A STUDY TO DETERMINE THE

OPTIMUM NUMBER OF GRAIN DELIVERY

POINTS IN SASKATCHEWAN WITH

PARTICULAR EMPHASIS ON THE CONSEQUENCES

FOR GRAIN PRODUCERS

A Thesis

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ABSTRACT

The Canadian Prairie grain collection system requires modernization. Centralization rather than replacement is being proposed as the answer to the demand for efficiency. The concern that motivated the study was for grain producers whose stake in the system has not been fully incorporated in analysis to date. Will centralization prove more efficient when the grain producer's stake is fully considered?

The system of grain collection defined in the study consists of 1) farm storage, 2) trucking, 3) roads, 4) country elevators and 5) railways. A cost minimization approach was adopted to analyze the problem which is incomplete but manageable and important.

A transportation - location model was used in the analysis. The model is rooted in a technique developed by Stollsteimer (1963) and incorporates a modification by Warrack and Fletcher (1970) to provide a sub-optimal solution for large problems. Modifications and additions were made to the Stollsteimer model in order to incorporate characteristics of the present system and also to deal with a range of decision variables (policy).

A computer program was constructed to aid in analysis of ten separate cases for an area of Saskatchewan. The ten cases represent a range of "what if" situations.

The results indicated that the savings from centralization in the study area are modest. The efficient number of grain delivery points varies widely and depends on a number of decisions not yet taken and a number of questions not yet confronted.

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CHAPTER I

INTRODUCTION

1.1 Introduction

Sixty million acres of Saskatchewan farm land produces about 750 million bushels of grain annually. Spring wheat destined for export generates 55 percent of total farm income in the province (Saskatchewan Department of Agriculture, Annual Report, 1974, p. 15). The current proportion of farm sales accounted for by transportation and handling from farm to ports approaches 20 percent. Transfer costs were traditionally double the above figure before the rapid rise in grain prices in 1973.[1/] It becomes apparent how important efficient handling and transporting grain is to the farm economy.

International grain marketing is increasingly more sophisticated making heavier demands on the grain collection system. Larger volumes of more varieties of grain are required thus increasing the complexity of coordinating flows from many small sources. The increased complexity combined with inflating costs and fixed freight rates increase the desirability of large scale inland terminals and unit trains.

1.2 The Need for Rationalization

The Canadian Prairie grain handling and transportation system was developed seventy-five years ago to serve the horse and wagon farmer.[2/]

1/ In 1969 the costs were $.50 for storing, handling and transporting wheat from country elevator through port terminal when wheat was selling for $1.50.

2/ For a historical review of grain handling and transportation in Western Canada see V.C. Fowke, The National Policy and the Wheat Economy, University of Toronto Press, 1957.

who has long since disappeared. Yet many of the features of that system remain today.

Farmers, on average, deliver grain to country elevator points within ten miles of their farms.[3/] A majority of grain elevators are fifty or more years old, small and poorly utilized. A large number of elevators are located on rail branch lines where grain is the only traffic. A common view among industry participants is that the system must be modernized; but therein lies the problem.

Although there is general agreement that modernization is required in grain collection there is no agreement on the precise manner in which this change ought to proceed. However, since 1960, a process of rationalization has visibly occurred in the form of consolidation and adoption of new technology. The number of country elevators is declining and more than one is commonly run by a single agent. Many of the smaller delivery points have closed entirely and their elevators moved to larger points or dismantled. The small number of new elevators recently constructed are large and designed for high throughput. Two inland terminals nearing completion[4/] are capable of servicing a unit train. The use of these terminals likely means that many delivery points will disappear.

1.3 The Impact of Centralization

The location of individual farmers and communities in relation to centralized delivery points will determine whether the trend to con-

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3/ See Canada Grains Council Information Booklet Area 12, Table 22, P.57.

4/ There is a one million bushel terminal of concrete construction nearing completion at Weyburn and a six hundred thousand bushel one at Rosetown.

centrated activity is viewed as positive or negative. Where old facilities are replaced the community and local farmers see net benefits. But, other locations will be closed in the process, producers will haul longer distances, and local communities will lose important business.

There is no single decision making body to direct changes in the grain handling and transportation system. Each individual or firm decides in its own interest what changes are potentially beneficial. However, consolidation in one sector can mean expansion in others. For example, closure of an uneconomic elevator point leads to a saving for the grain elevator company and for the railway which has one less point to service. The closure requires farmers to haul their grain to the next open point, an added expense to them. Although the net cost or benefit is important when considering the whole system; everyone is not likely to benefit, at least in the short run.

Arguments have been presented (Grains Group, August, 1971, p. 6; Saskatchewan Wheat Pool, 1975, pp. 2-3; and Cargill Grain Co., 1975, p. 7) that efficiency in rail and elevator operations resulting from innovation and consolidation will be reflected to the grain producer by way of lower charges or at least charges will not increase as quickly as might otherwise be the case. These arguments of "common interest" are not necessarily true. One way to determine the argument's validity is to incorporate the producer's position <u>directly</u> into an analysis of the grain collection system.

The cost to grain producers of marketing grain includes more than the charges of elevator and rail companies. The view that a farmer is simply a customer of the grain industry is inadequate because it leads to narrow objectives which can and do conflict with grain producers' interests. The gains may be illusory (Hesket, 1965, p. 145) if more complete producer costs are not included in the total system cost.

Closing elevators, delivery points, and abandoning branch lines will lead to savings for the grain industry but adds to costs for some farmers. There will be a need for newer, larger farm trucks (Kulshreshtha, 1974, pp. 43-51) which is an added cost to the farm business. Grain production is by nature a "batch" process which means that reduced commercial storage, implied by consolidation, is reflected to grain producers in added farm storage costs (Setter, 1970, p. 19).

The municipal road network over which farmers haul their grain is financed largely through land taxation. Because this is not a user tax it is not included directly in the cost of farm trucking. The provincial highway system is financed through license and fuel taxes, but the license paid on farm trucks is minimal and farm truck fuel is tax exempt. Highway costs are born by the grain producer only to the extent of his license and in his capacity as a taxpayer. The bulk of the grain hauling cost on highways is a cost to the provincial public.

In the long run centralization has implications for the enterprise mix on farms, the service provided to each producer, and the competitive position of one farm in respect to another. But, is a centralized grain collection system, with its impact on grain producers, going to improve the future competitive position of the Prairie grain industry? Will it be more efficient?

1.4 Definition of the Problem

To study all the economic implications of changing the grain collection system would require a comprehensive conceptual and empirical model beyond the scope of this study.[5] There are, however, some important cost questions which need and can be answered. How many delivery points are required? In what configuration should they be arranged? How large should each facility be and how many should there be at each point? How much grain should each one handle? Additional considerations may be ignored in favor of costs for two reasons, (1) there are simply too many variables many of which are not easily measured and thus cannot be analyzed effectively in one study and (2), although cost minimization is a simplistic approach for a system as complex as grain handling, it provides a foundation for continued profitable production. Also, it is important to examine the relative cost of alternative configurations in relation to a least cost solution. The cost question, once addressed, can help formulate policies about other economic, social, and political considerations.

Briefly, the analysis considers a number of "what if" situations for a single time period (1974), emphasizing the spatial-cost dimensions of the grain collection problem.

1.5 The Scope of the Research

The Canadian grain collection system is complex. Consequently, this analysis is limited to those components related directly to the grain producer specifically, storing, handling, and transporting grain

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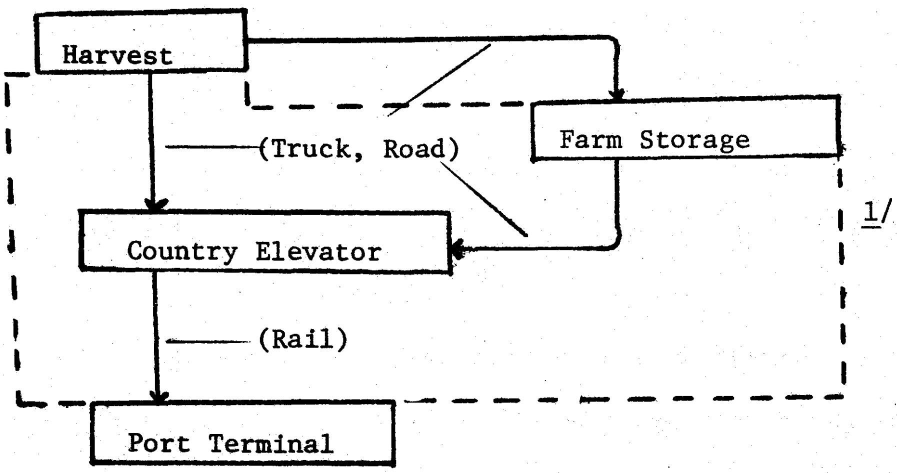
[5] The focus of this study will ignore many factors such as the change in service and community effects. It also ignores markets and changing competitive positions. Similarly, it does not say anything about what country elevators should do or the functions that could be carried out in them.

from (including) the farm to (but excluding) port terminal elevators (port terminals are excluded because no change is contemplated in their role in the system). The cost relationships between producers, elevators, and railroads is generated by trucking, storage, and road maintenance data.

This study considers five major components (see Figure 1.1): (1) a set of costs associated with farm trucking under various operating and

Figure 1.1 Focus on the System



1/ The system being considered includes the portion inside the broken line.

delivery patterns. Farm trucking from field to farm storage is ignored for lack of information and no differentiation is made between the cost of trucking direct versus from farm storage; (2) costs associated with the roads over which trucks move grain. Road costing, explained later in detail (pp. 18-20) is extremely complex and is ultimately treated in aggregate after analysis of other components; (3) costs in connection with the operation of country elevators which vary with size, number, handling and storage; (4) costs of transporting grain by rail from elevators to port terminals that are determined by the size of shipment, equipment used, the nature of the rail line and the number of elevators requiring service; and (5) costs of farm storage (which is the residual once the storage capacity of the country elevator network is determined).

1.6 The Objective of the Study

The major objective of this study is to confront the process of elevator centralization to determine the extent of anticipated savings. Although there are an unlimited number of combinations of locations and equipment that can be assembled to perform the function of grain collection this analysis claims only to identify differences in costs associated with selected changes in the collection system. A transportation-location model is used. The particular technique was initially developed by Stollsteimer (1963), modified by Warrack and Fletcher (1970) and further modified in this application.

1.7 The Area Selected for Study

The study area is located west of Saskatoon between the North and South Saskatchewan rivers and extends to the Alberta boundary. The designated area is expected to be affected more by consolidation than most other parts of the province because it has a relatively high portion of rail branch lines (see Figure 2.1). The area includes a major portion of the area 11 study conducted by the Canada Grains Council. Much of the data used here is taken from this study, particularly with regard to farm delivery distances, elevator and commercial trucking costs. The natural boundaries on three sides of the area tend to provide a form of insulation thus reducing error from boundary effects. Potential errors resulting from the movement of grain across the border is minimized because there are no rail lines which parallel the boundary between Saskatchewan and Alberta.

CHAPTER II

THE GRAIN COLLECTION SYSTEM

2.1 Introduction

The purpose of this chapter is to briefly describe the components of the grain collection system including recent economic activities.

Considerable energy has been spent in recent years looking into various aspects of grain transportation problems in Saskatchewan and the Prairies. Most of the studies were directed toward identifying cost and technical relationships to find the changes that would lead to industry efficiency. Information has also been gathered on the grain producers' stake in the industry but it has not been incorporated directly into a systems analysis where the industry configuration could be influenced by its relationship to grain producers.

2.2 Country Elevators

In studies recommending centralization of elevator points the location pattern is often imposed on the system before cost accounting takes place. The approach takes the form of an assumed optimal location pattern (Grains Group, Aug. 1971, p. 8) or abandonment of small delivery points, and closure of points on particular rail branch lines (C.G.C., pp. 10-13). A preferable approach to the problem may be to incorporate location as a variable in the analysis.

An indepth analysis of factors affecting efficiency in country elevator operations was conducted in 1967 (Zasada and Tangri). The single most important factor in low cost operation was the handling to capacity ratio (Zasada and Tangri, p. 81). The above evidence and continuing inflation leads to the conclusion that the consolidation of facilities would help hold the line on costs. Although economies of scale were thought to exist, the handling to capacity ratio for large elevators was observed to fall (Zasada and Tangri, p. 93) so any potential savings from these facilities were negated due to competition for limited amounts of grain.

Most elevators are 50 or more years old (Table 2.1, p. 11)[1/] and are small by today's standards. The largest of the grain elevator companies in Saskatchewan operates 62.6% of all country elevators. The four largest firms own 97.7% of all elevators. Two of these four companies including the largest are farmer owned co-operatives, operating 75.3% of all elevators in Saskatchewan. The number of elevators declined rapidly between 1965 and 1974 as did the number of delivery points. The number of single company points increased primarily due to the sale of Federal Grain Ltd. in 1971 and by trading among companies to establish multiple unit, one company operations at a point. Table 2.2 indicates the trend of change from 1965 through 1968, 1971 and 1974. The declining number of elevators, points and reduced competition at remaining points are all of concern to producers. Historically farmers have invested time and money to insure they would not be exploited by monopoly power. There remains a feeling common among farmers that 'opposition' (countervailing power) is inherently beneficial.

[1/] A note of caution must be entered when interpreting this table. Data used to determine the age of elevators is based on the first year for which a license was issued by the C.G.C. This does not take into account any subsequent additions or renovations or equipment replacement. For an individual elevator, age, as given here, can be a misleading indicator of life expectancy. This is likely the case for the larger, old facilities as many of these would have had annexes attached to the original structure.

Table 2.1

Age and Size Distribution of Elevators in Saskatchewan, (1972-3)

Storage Capacity (Bushels)	Age (Date of Construction)							
	Pre-1921	1921-1930	1931-940	1941-1950	1951-1960	1961-1970	After 1970	Total
Less than 25,000	79	28	3	0	0	0	0	110
25,000 to 45,000	121	188	24	1	8	3	0	345
45,001 to 65,000	163	279	35	11	42	9	0	539
65,001 to 85,000	172	222	46	19	84	15	0	558
85,001 to 105,000	87	159	30	18	79	42	3	418
105,001 to 125,000	45	78	22	21	48	17	1	232
125,001 to 175,000	37	54	23	23	45	57	0	239
175,001 to 225,000	4	4	4	0	8	19	0	39
225,001 to 300,000	1	1	2	0	0	5	0	9
Greater than 300,000	0	1	0	0	0	2	1	4
Total	709	1014	189	93	314	169	5	2493
Percent of Total	28	41	8	4	12	7	--	100

Source: Kulshreshtha, September 1975, p. 29.

Table 2.2

Change in Elevator Operations 1965-74

Companies/Pt.	(Year)	Elevators/Pt. 1	2	3	4	5	6	7	8	10	11
1	'74'	145	204	93	19	4	1				
	'71'	224	134	34	4	1	–				
	'68'	253	59	4	–	–	–				
	'65'	265	55	2	–	–	–				
2			67	115	67	21	8	2			
			143	154	51	9	2	–			
			233	154	47	6	1	–			
			245	147	35	6	1	–			
3				21	33	28	18	2	1		1
				51	63	33	14	1	2		–
				74	82	27	10	1	2		–
				85	80	26	8	–	–		
4					4	8	2	1	–		–
					15	24	11	6	2		1
					25	26	18	5	2		–
					46	31	18	7	3		
5						1	–	–			–
						3	–	–			–
						7	–	1			1
						10	3	5			–
6							–			–	
							–			–	
							1			–	
							1			1	

Year	Points	Elevators	% 1 Co. Pts.
74	863	2397	54.6%
71	991	2673	40.6%
68	1041	2758	30.7%
65	1067	2849	30.2%

Source: Canadian Grain Commission, Grain Elevators in Canada.

2.3 Railways

Railways find themselves in a complicated set of circumstances with revenue frozen in a period of rapid inflation. There are two railway companies operating 8,603 miles of track in Saskatchewan. Grain represents a major portion of their revenue traffic and is the only traffic of consequence on the 3,636 miles of track that are branch lines (see Figure 2.1).

Railways are required by law to haul grain at rates in effect in 1897. Since the rates are fixed and grain is virtually the only traffic left on branch lines, abandonment is a logical way to avoid rising costs. This would concentrate grain collecting activity on main lines where it could be hauled at a lower cost. Abandonment, however, has important economic and social implications for those producers and communities losing rail service.

A study of the Brandon area of Manitoba (C.G.C., 1974), examined the possibility of rehabilitating branch lines to a level capable of carrying fully loaded hopper cars. They concluded that costs for hauling grain on branch lines would be 3 to 4 times the cost incurred on main lines.[2/]

In 1959 a Federal Royal Commission chaired by M.A. MacPherson reviewed transportation policy in Canada. One of the recommendations which came from their report was that railways not be held responsible

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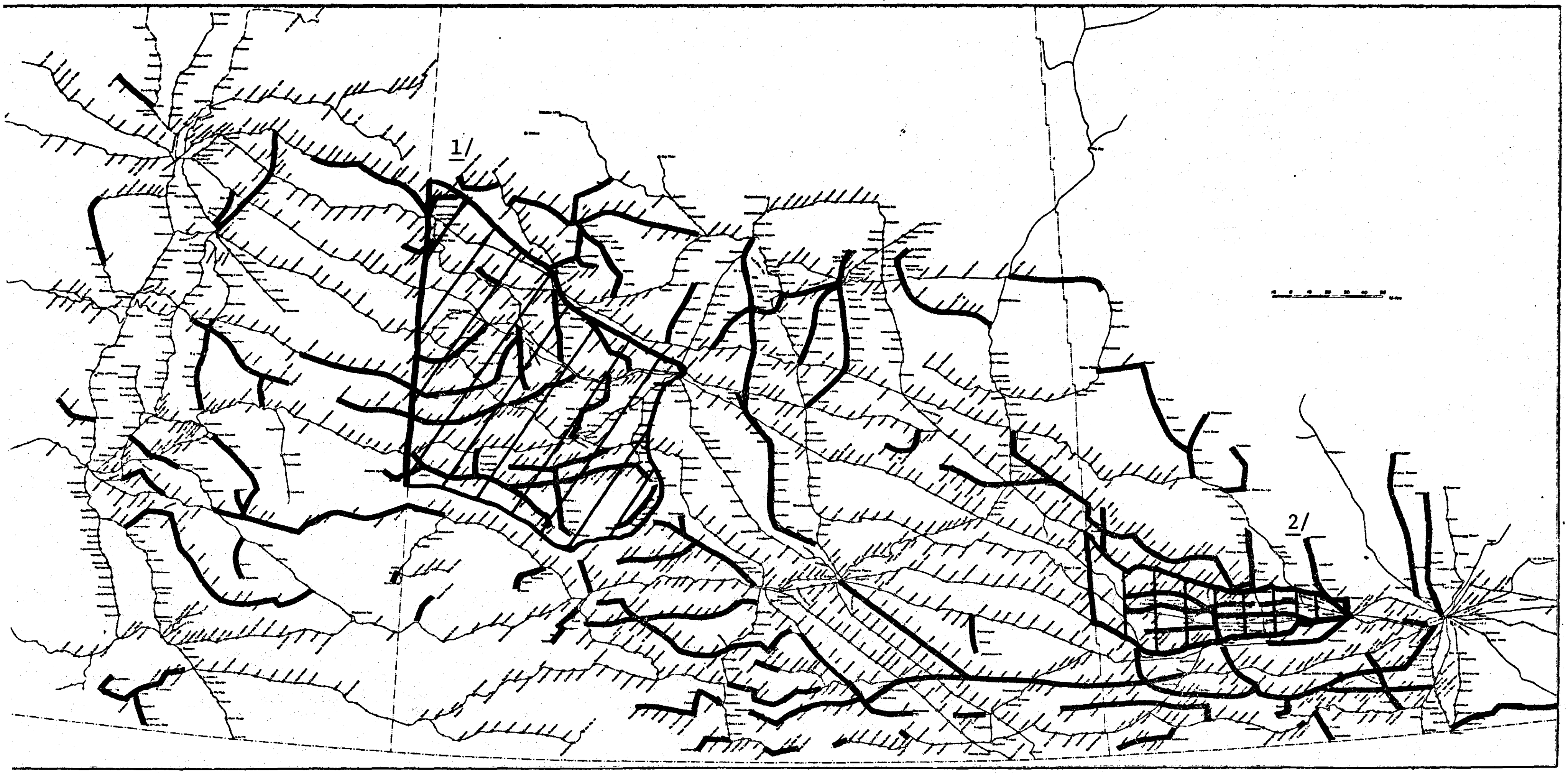
2/ It should, however, be noted that the Brandon area is not typical of the rail configuration on the Prairies. There are many parallel lines concentrated in a small area so the drawing distance for a particular line is short in relation to the normal Prairie situation (see Figure 2.1). The cost for rehabilitation on a bushel basis would generally be lower than in the Brandon area because of the greater drawing distance found for most rail lines in the Prairies.

Figure 2.1

Canadian Prairie Provinces
Rail System



Source: P.S. Ross & Partners, August 1971, Exhibit 2

1/
Study Area

2/
Brandon Area

LEGEND

Light Density
Traffic Lines

for public policy re: the Crow's Nest Rates on grain[3/]. A temporary freeze on branch line abandonment was initiated to provide time to study the problem and a subsidy[4/] was paid to the railways for unavoidable losses in place of a rate change until the whole area of grain transportation could be studied. The result of this situation is deteriorating road beds, service and failure of railways to place rolling stock.

The federal government is in the process of supplying railways with 6,000 hopper cars to haul grain[5/]. The unit train which uses hopper cars has reduced costs. A United States study that examined similar grain handling problems (Baumel, 1973) concluded that (1) traditional single car movement of grain from elevators was the most expensive and (2) the unit train servicing large terminal elevators was the least expensive alternative studied.

It appears that consolidation offers real improvement for the industry when one couples the saving in rail cost with the already observed saving from high turnover in grain elevators. The area which requires more information and analysis is how the above savings relate to grain producers. The industry-customer relationship between the

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3/ The rates on grain are held constant by a 1925 amendment to the Railway Act which bound railways to haul grain from the Prairies at rates agreed to by the Federal government and Canadian Pacific Railway in 1897 - The Crow's Nest Pass Agreement.

4/ In 1974 the Federal Government paid $62,593,798 to the railways as a subsidy to haul grain from branch lines.

5/ The cars are used on main lines as they are too large for most branch lines to support their loaded weight.

elevator and rail companies on one hand and, grain producers on the other does not provide a complete explanation of the interrelationship.

2.4 Farm Trucking

Most commercially marketed grain in Saskatchewan is delivered to country elevators from farms from a distance less than 15 miles. Farmers deliver from 5 to 15 thousand bushels of grain each year in small general purpose trucks. Custom trucking usually occurs between neighbors and little commercial trucking exists.[6/]

The farm truck fleet is characterized by a number of factors. It is old, small and is not highly utilized.

The average grain truck in 1972 had a capacity of 215 bushels. The size of truck is primarily related to the volume of grain to be delivered from the farm and the distance to country elevator (Kulshreshtha, August, 1973, pp. 43-45). Thus, as collection becomes centralized at fewer points and distances increase to elevators, larger trucks are required.

The average truck in 1973 was 15.5 years old. The age of the truck was related to the amount of grain delivered from the farm and distance to delivery point (Kulshreshtha, August, 1973, pp. 45-51). Newer trucks will be used[7/] as consolidation of delivery points occur. The expense

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6/ With the development of a local oilseed crushing industry semi-trailers are used to haul rapeseed where distances up to 100 miles are common.

7/ The replacement cost for a new farm truck is 8 to 10 times the value of the average truck in 1972.

of changing the truck fleet will be born disproportionately by the few producers located near closed points. The effect will be less noticeable as the individual is located nearer the boundary between closed and open delivery points and not felt by producers whose point does not close.

2.5 Farm Storage

Most grain harvested on farms in the Prairies was traditionally hauled to farm storage bins and subsequently hauled to elevators as space and time permitted. In the most recent 25 years virtually all grain was first stored on the farm as elevators were full with grain carried over at harvest time. Indeed in 1971 thirty percent of farm supplies were carryover in addition to the full elevators. Farm storage equalled farm supplies at that time.

Any grain delivered direct from field to elevator avoids the storage cost on farm and the extra handling. Since cropping is a batch process the total produced must be stored somewhere. Any decrease in storage, implied in centralization of elevator points, will be reflected to farmers through increased on farm storage requirements. Farmers more distant from delivery points would need to store their entire crop even when space was available because longer delivery distance would interfere with the harvest process. Near farmers have the potential to deliver but this would violate the traditional equal access rights of farmers assured by the quota system of the Canadian Wheat Board.

There is a significant cost reduction in elevator operations as the handling to capacity ratio is increased. If farmers are capable of filling the present elevators' capacity during harvest any increase in the handling to capacity ratio requires increased farm storage. If, for example, they could fill only one half the space available then storage could be reduced in the commercial system by one-half with no affect on farm storage cost. The more dispersed the delivery points and shorter the average hauling distance the greater farm capacity to deliver direct to elevators and avoid duplicate storage and handling.

2.6 Roads and Highways

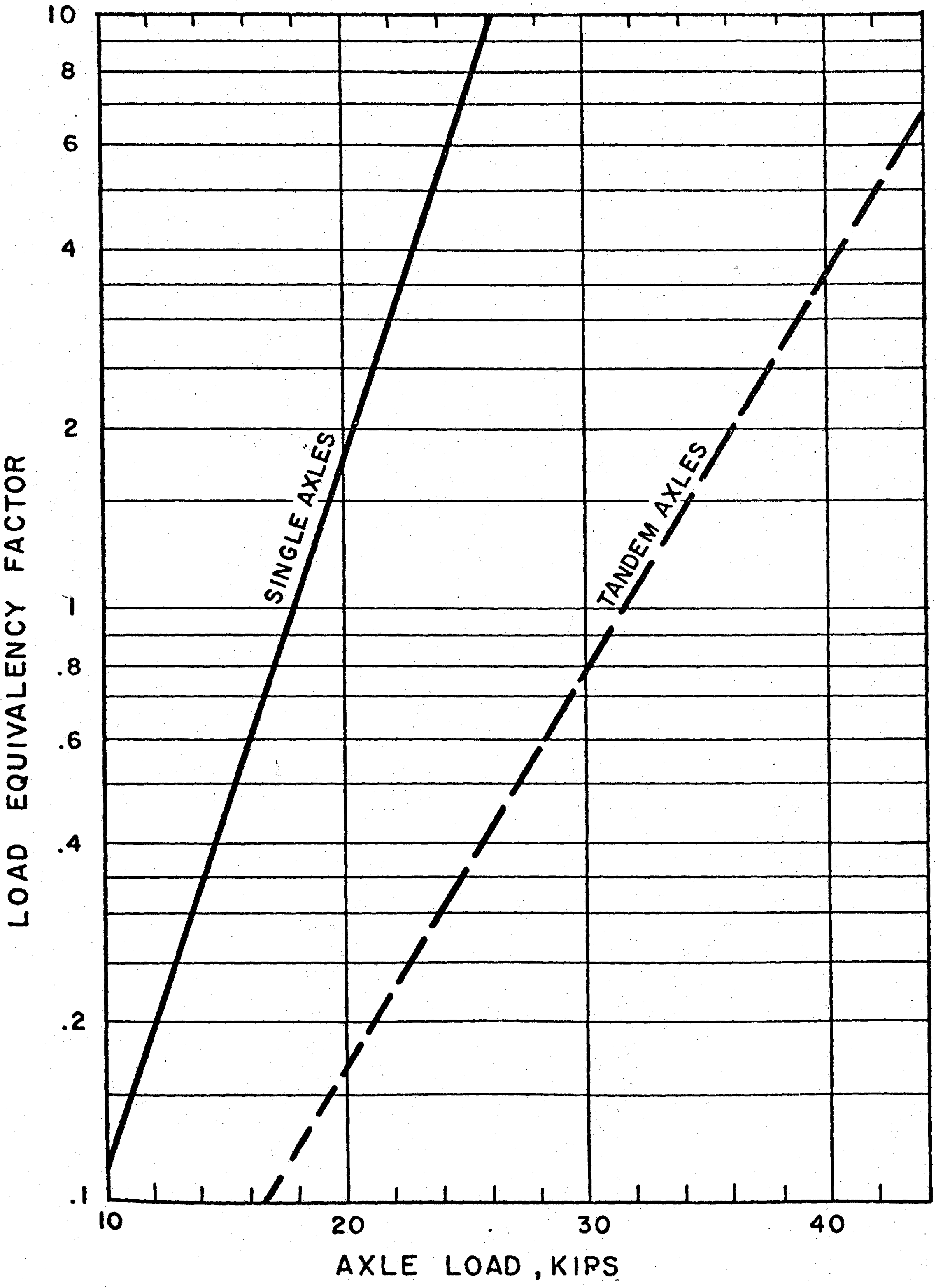
The final component examined in the system is the cost structure of roads for moving grain from farms to elevators. The municipal road network, maintained through property tax assessment is omitted from the estimates for trucking because there is no user tax. Research indicates that centralization of grain collection can lead to substantial increases in road costs (Shurson, p. 93) for Saskatchewan.

As noted in Section 2.4, the size of grain trucks is related to distance to delivery points. What implications do larger trucks hauling longer distance have for the road system? An extensive study of roads and highways was conducted in the U.S. for the American Association of State Highway Officials which provides a basis for road costing. The Saskatchewan Department of Highways used two formulas (see Figure 2.2) which express single and tandem axle loadings in 18,000 pound (18 KIP) equivalents (S.D.H., pp. 9-10).

If it can be determined that a given road surface can sustain a given number of standard axle load passes then knowing the construction and maintenance costs a cost per bushel mile or truck mile can be calculated for each size of truck. This method was used by Baumel (pp. 230-238) to determine added road costs for a centralized grain collection system. The implication from the change in truck size and the load factor relationship is the cost of roads will increase exponentially as delivery points are closed (Figure 2.2).

Figure 2.2

Load Factors for Single and Tandem Axles



Source: Saskatchewan Department of Highways, Portable Truck Axle Weight Study, 1973, p. 10.

CHAPTER III

THEORY AND CONCEPTUAL DESIGN

3.1 Introduction

Activity and location are two major determinants of efficiency. The purpose of this chapter is to define and employ the concept of efficiency in a partial sense where selected components are analysed in isolation. The analytical model, presented in Chapter IV, will then serve to operationalize these concepts and provide the methodology for reconciling the isolated considerations.

Section 3.2 deals with short and long run cost concepts for a plant and is designed to demonstrate how to conduct an activity efficiently. A 'plant' as defined here includes the equipment and facilities associated with activities such as the operation of elevators, trucks and railways.

Section 3.3 deals with factors that affect economies of scale, which are important in the analysis because of centralization or decentralization in grain collection.

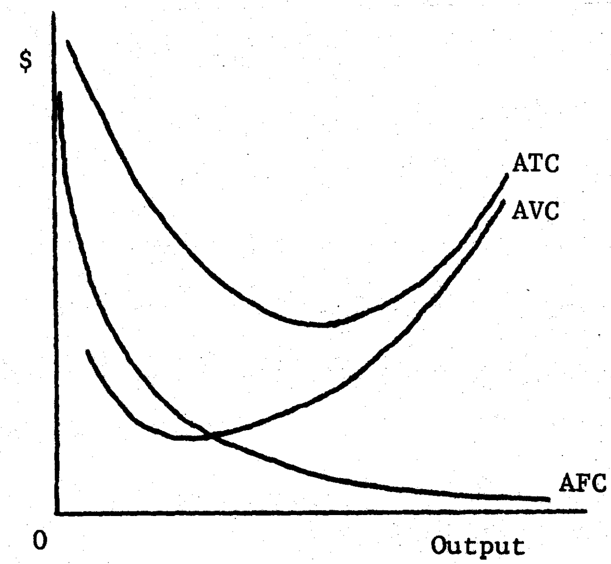
The remaining sections examine selected transportation and location issues. Location theory provides the conceptual link for a series of spatially isolated activities that form the grain collection system. Section 3.4 deals with transportation factors such as the applicable modes, distance and rate structure. Section 3.5 considers market area which is particularly important in determining the number and location of grain delivery points.

Combining activity and location theory can lead to a technically more efficient collection system. However, a potential conflict between technical efficiency, employed in this analysis, and market efficiency, ignored in the analysis is elaborated on in the closing paragraphs of the chapter.

3.2 Short and Long Run Costs

In the short run costs are composed of two components, fixed and variable[1/] (Ferguson, pp. 210-221). Fixed costs are associated with resources committed to an activity which are not avoided even at zero level of output. Variable costs are associated with inputs that vary with the level of activity or output. These are presented graphically in Figure 3.1.

Figure 3.1 Short Run Cost

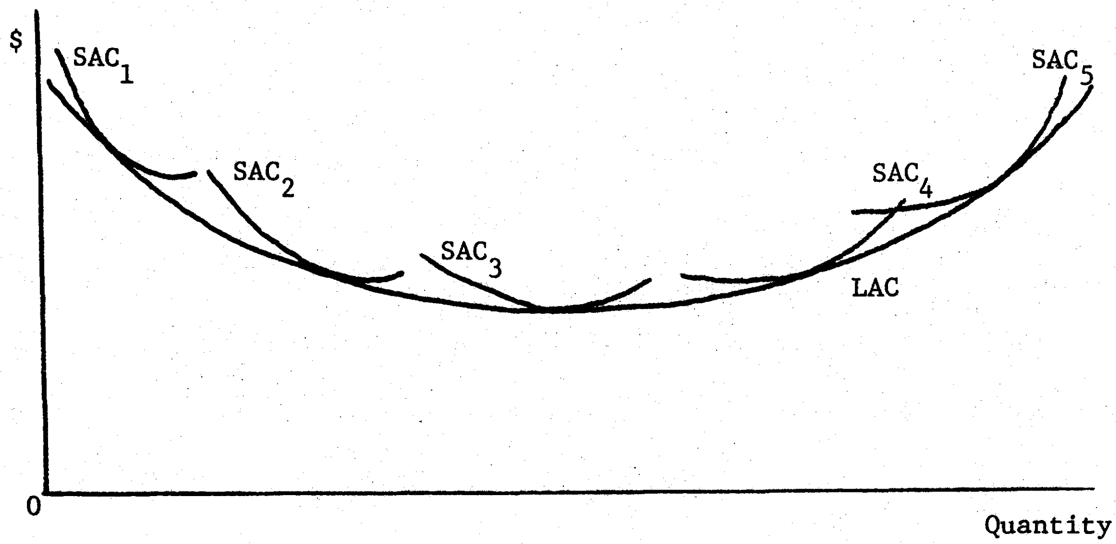


Source: Ferguson, p. 221.

[1/] The short run period in practice is usually restricted to a time period where plant and equipment are committed to an activity.

In the long run all inputs required in an activity are variable. The long run is normally referred to as the planning horizon where the type and scale of activity are decided on. Long run costs are presented graphically (Figure 3.2) as an envelope curve of short run average total cost curves derived by considering all scales of plant (Ferguson, pp. 221-226).

Figure 3.2 Long Run Cost



Source: Ferguson, p. 224

Note in the Figure 3.2 there is a declining and an increasing portion for each of the curves. The interpretation attached for first declining and then increasing portions of each SAC is derived from increasing and decreasing marginal returns as the variable input is first extensively applied to fixed inputs and then intensively applied. The application of variable to fixed inputs leads to the concept of efficient use of plant. This is the minimum point on each SAC curve (cost approach).

The falling and rising portions of the LAC curve are interpreted as economies and diseconomies of scale. The efficient scale of plant is represented by the minimum point on the LAC curve[2/]. At this point efficient scale of plant coincides with efficient use of plant, i.e. the minimum point on SAC_3 corresponds to the minimum point on LAC. For example, in this study elevator efficiency is determined by size as expressed in the storage capacity and use as expressed in the annual handling to capacity ratio. Similarly truck efficiency is determined by size as expressed in grain box capacity and use expressed in annual miles.

3.3 Economy and Diseconomy of Scale

Most economic activity takes place at discrete centers, for instance grain handling occurs at discrete elevator points. The degree of centralization and number of centers of activity can depend largely on economies and diseconomies of scale (Bos, p. 12).

There are a number of factors leading to scale economies and concentration of economic activity. First, some minimal assembly of resources (given sufficient demand) is required to initiate an activity. A minimum level of resources is necessary because many inputs come in indivisible units which must be matched so that resources are not tied up and then left partially idle. The smallest efficient scale for an activity is the least common multiple of its indivisible inputs (Hoover, p. 79).

2/ Emperical studies (see Warrack, CJAE, V. 20, No. 3, pp. 9-22 for example) suggests the apparent shape of the LAC is flat beyond some minimum. The inclining portion may, however be masked by market power or the difficulty of evaluating changing markets in the long run.

Second, most of the advanced technology available is highly capital intensive. Only a high level of concentrated activity over a long period can utilize the large initial investment efficiently. Large scale activity opens up the opportunity to conduct bulk transactions and to exert influence in the market.

Diseconomies of scale lead to decentralization. Two major factors are involved. As the scale of plant becomes large expenditure on communication and administration increase more than proportionally[3/].

A second source of diseconomy of scale, often overlooked, is large scale investments commit resources for long periods of time during which both markets and technology are susceptible to change. As the pace of change accelerates, as it appears to have done over the last 50 years, this source of inefficiency becomes a real concern to planners. Hoover (pp. 80-81) suggests that due to their fixed nature highly specialized, highly capitalized plants should be avoided. Over capitalization in such plants may result in resistance to change thus stalling progress. Diseconomies associated with assembling information, changing technology and changing markets are not addressed in the analytical model because of difficulties operationalizing them. They are mentioned here because they are important and because they temper interpretation of the results in Chapter V.

From the discussion on costs it is evident that efficiency may be dependant on both size and use of plant often thought of as the internal factors. There is also interaction with a set of external factors,

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[3/] The information required is on local conditions which is possessed by people in localized activity but not by a head office remote from the site (Isard, p. 80).

present in the immediate spatial environment, which complicates the determination of the optimum number and size of plants required to serve the market.

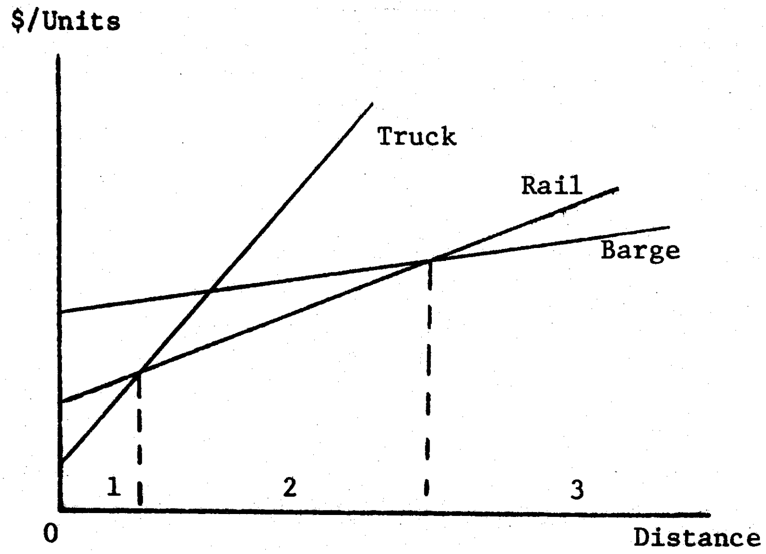
Transportation cost is a major location and size determinant, as are the attributes of individual locations. Competition among firms for the market and the degree of certainty about the future market are also important factors.

Site differences lead to economy or diseconomy because many services required as inputs for an activity are shared by numerous firms. Transportation and communications networks are good examples. Industries using transportation intensively for inputs and/or products are attracted to main highway and rail arteries. Not all effects of association, however, are favorable, these sites are also associated with conjestion and unproductive travel time.

3.4 Transportation

Where transportation is a significant portion of the delivered cost of a commodity it is an important determinant of plant location. The particular mode selected for transportation of a good to market varies with the distance between the market and source of supply. Trucks, for example, are characterized by low fixed and high variable costs. They are relatively economical for short hauls. Barge on the other hand is characterized by high fixed and low variable cost and is, therefore, suitable for long hauls. Railway costs are located between the two extremes, see Figure 3.3. For some products or locations only one or two of the modes may be applicable. A perishable

Figure 3.3 Comparative Efficiency of Transportation Modes



Source: Hoover, p. 20

product moving a long distance may be moved by truck in order to have it arrive in an unspoiled condition. Similarly, inland locations do not have the barge option open to them unless a navigable river exists. The grain collection system uses truck and rail modes which are related to each other as shown in Figure 3.3. Trucks are used for short haul and rail used for long haul.

Aside from the cost of transportation, there is a rate structure which will influence the choice of mode and plant location. The rate structure for rail would be devised to take advantage of the zone in which it had the advantage by charging greater than full cost.[4/] It could charge less than full cost in zones 1 and 3 to attract traffic from other modes (Figure 3.4). The rates, where less than full cost,

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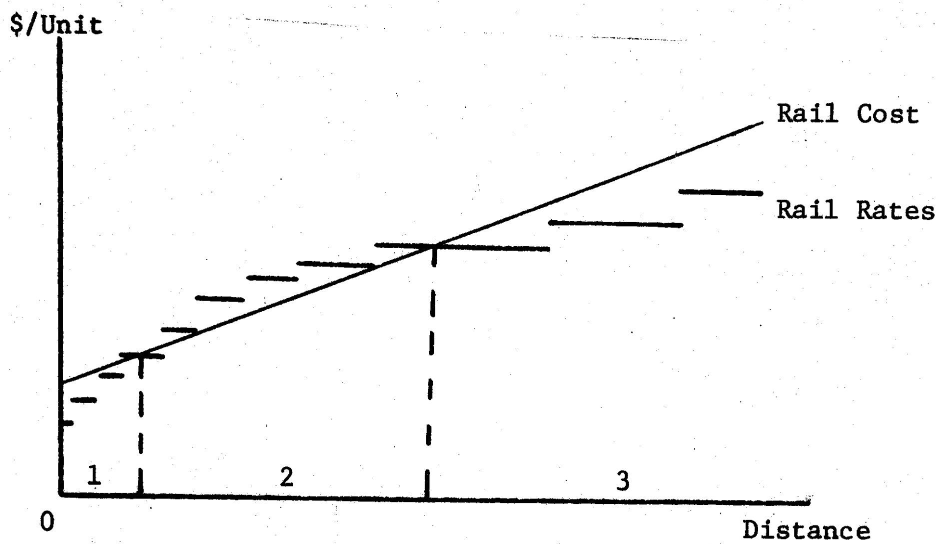
4/ In the case of grain transportation by rail a rate structure (Crow's Nest Rate) is employed but is fixed by statute and does not bear the relationship to costs demonstrated in Figure 3.4

Figure 3.4 Transportation Rate Structure



Source: Hoover, p. 21

would have to cover variable cost plus some return to fixed. The stepwise rate structure is common in practice as it avoids administration of varying rates for every point from or to which goods are moved. Plant location does not depend on transportation within any one zone but is sensitive to changing zones.

Transportation is characterized by costs which must be shared by products moved together in one trip or as a backhaul on the return trip. Some degree of discretion is required to allocate these costs.[5/]

3.5 Transhipment

Given an appropriate set of circumstances more than one mode of transportation can be used effectively in delivering a commodity to

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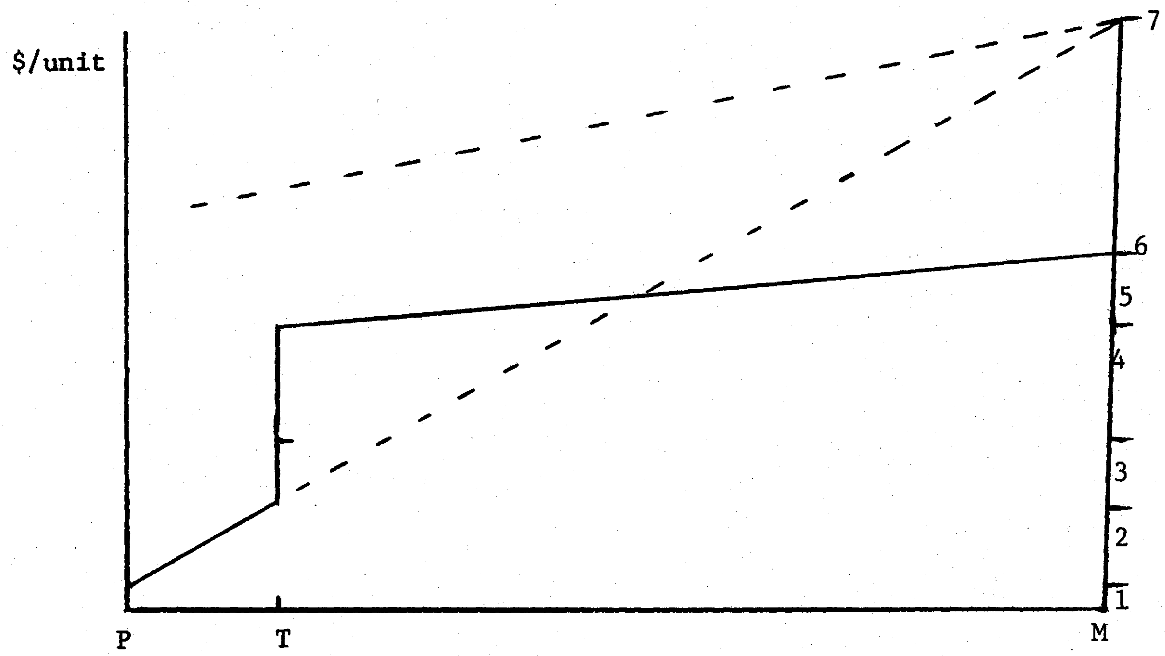
5/ This is a problem in allocating the cost of trucking from farm to elevator where the trip has more than one objective. The farmer may deliver grain, conduct other business and return with farm supplies in one trip.

Figure 3.5 A Case for Transhipment



P = production site

T = transhipment center

M = market

1 = fixed truck cost

2 = variable truck cost

3 = transhipment costs

4 = fixed rail cost

5 = variable rail cost

6 = total cost when transhipment is employed

7 = alternate total cost when no transhipment is employed

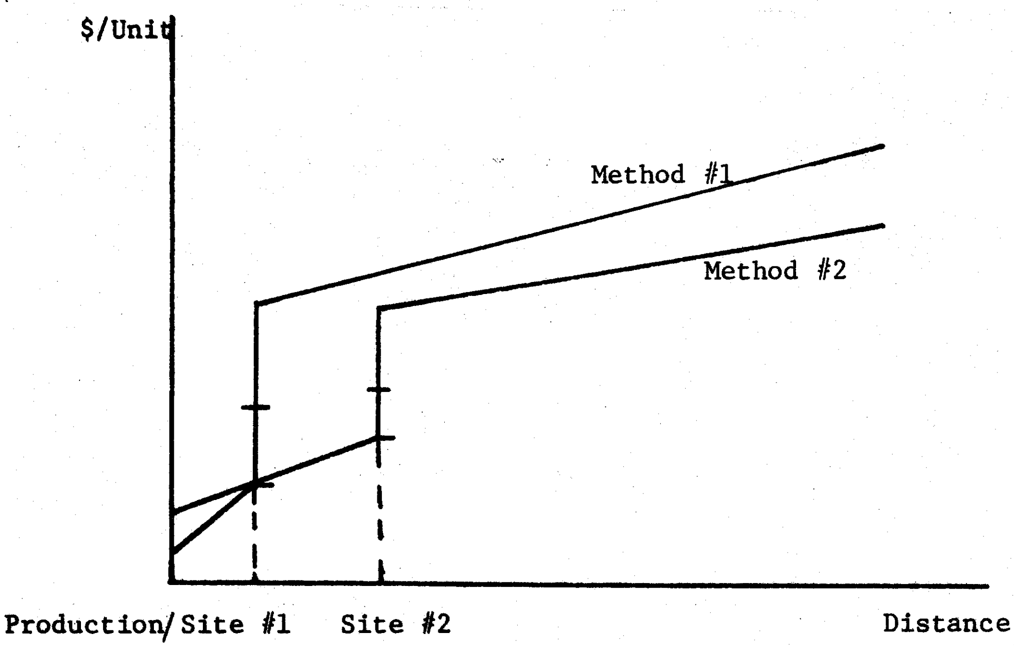
Source: Hypothetical example

market. A case for transhipment arises where production is spatially dispersed and the market is distant from the producing area. This is the case for grain marketing. Trucks are used to assemble small quantities over short distances, transferring the commodity to the next mode at a transhipment point. The product can be sorted and assembled at these locations for larger unit shipments by rail over long distances to market.

The rational for transhipment focuses on the choice between the high variable cost of transfer by truck alone and the high fixed cost of movement by rail. Both alternatives are expensive when compared to the added facility cost required for transhipment (Figure 3.5).

The appropriate location for a transhipment point is determined from the least cost combination of truck, rail and plant costs. From Figure 3.6 we can demonstrate the relationship between location and cost. Method 2 is preferred as it leads to least cost. Larger trucks represented by greater fixed and lower variable costs are employed to service a site at greater average distance from producing sites. Transhipment (plant) costs decline, showing economies of scale or efficient use. Rail costs both fixed and variable decline as there are fewer sites to service and larger shipments from each. Whether Method 2 (Figure 3.6) is in fact more efficient than Method 1 is the question confronted by researchers in the grain collection problem.

Figure 3.6 Preferred Site for Transhipment



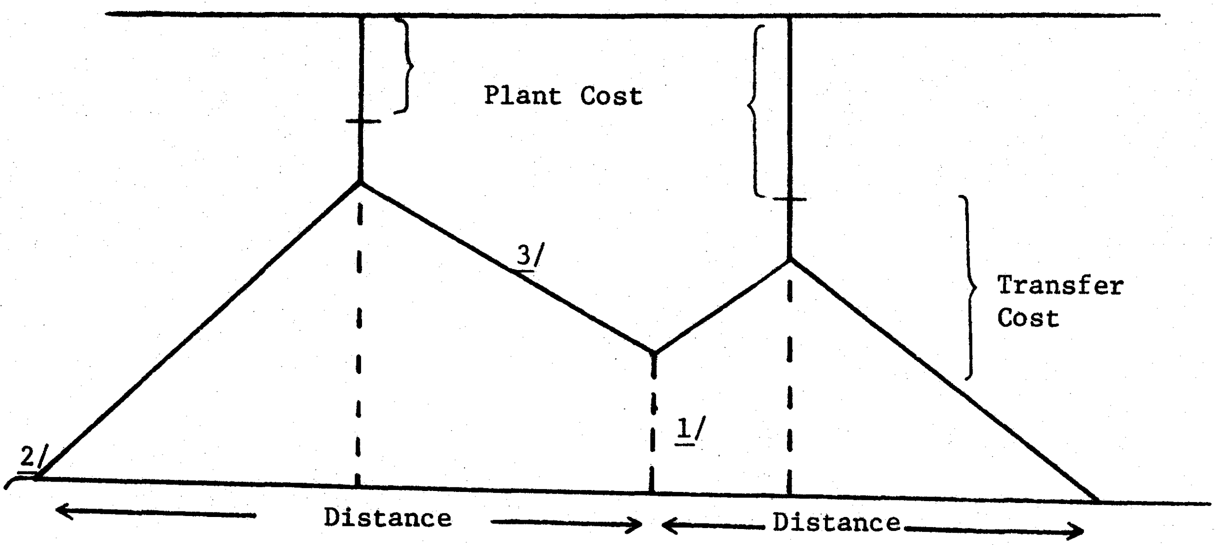
Source: Hypothetical example.

3.6 Market Area as a Determinant of Plant Location

How is the drawing area for an assembly site determined? There are many contributing factors but only those consistent with the cost approach are considered here. Some of the most important factors are plant cost, transfer cost, cost of production, neighboring sites and the transportation network. Figure 3.7 illustrates how the drawing distance for two sites is determined a) by plant cost, b) by transfer cost, and c) by each other. Where no transportation network exists and where equal access is assumed, the market shape around an isolated plant is a circle (Figure 3.8). Where firms compete for sites the most efficient market area is hexagonal[6/]. The largest size possible

[6/] For a proof see (Losch, pp. 111-112)

Figure 3.7 Market Boundaries



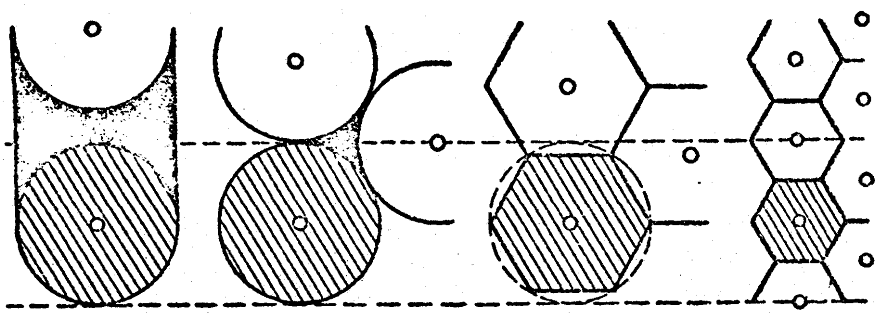
1/ Market boundary determined by competition

2/ Market boundary determined by transfer cost

3/ Realized producer price dependent on location

Source: Bressler and King, p. 128

Figure 3.8 Lösch Hexagonal Market Area

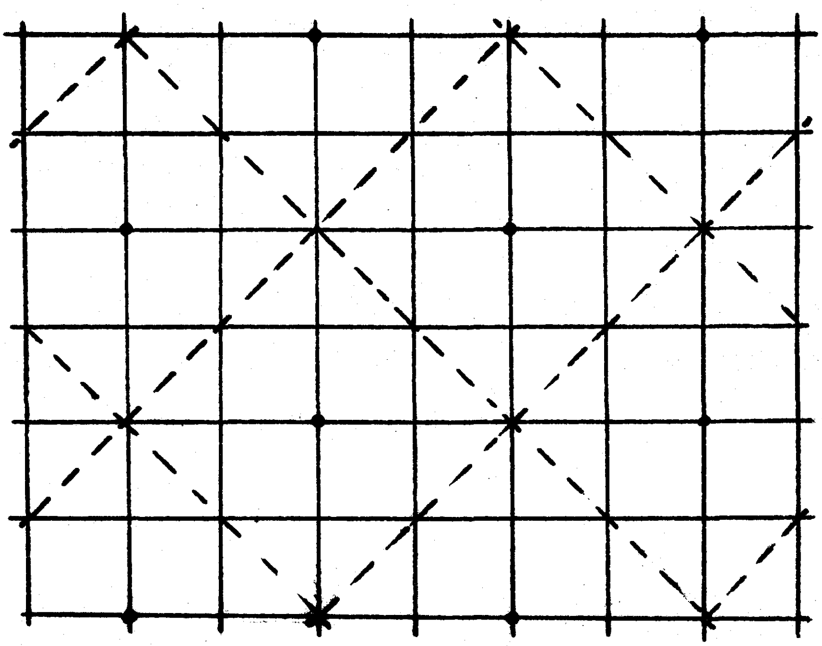


Source: August Lösch, The Economics of Location, translated by W.H. Woglom, p. 110.

for the hexagonal market is the size where the corners of the hexagon coincide with points on the circumference of an isolated circular market. The smallest is that which will generate sufficient activity for a plant to break even.

In a situation where equal access does not exist but a grid network of transportation routes is imposed on a plane the market shape is altered as represented in Figure 3.9 (Bressler, pp. 112-114).

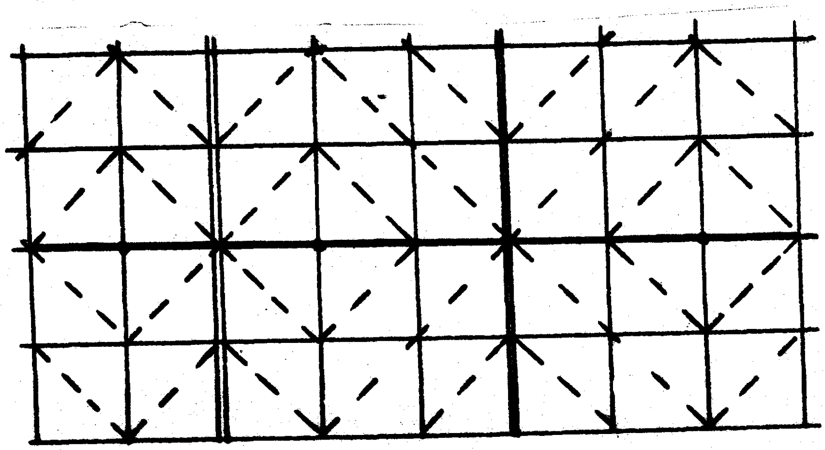
Figure 3.9 Market Area in a Transportation Grid A



Source: Bressler, p. 113

A further restriction is applied. Where goods are moved on a grid to transhipment points along a line the market shape is further altered as demonstrated in Figure 3.10. The market area determined by both the grid network and single line on which sites are located leads to a market shape for which the distance to the site is not equal for

Figure 3.10 Market Area in a Transportation Grid B



Source: Example area

all points on the boundary as was the case in Figures 3.8 and 3.9.

3.7 Efficiency vs. Spatial Monopoly

Competition among firms was one of the determinants of market areas. A producer will deliver to the nearest site where market price and plant costs are the same between locations and assuming transportation cost varies with distance only. Market boundaries will be equidistant between two neighboring points. There is, however, a possible conflict in this situation. How can efficient market area be reconciled with implied spatial monopoly at each site? Alternatives exist. It is possible that only a limited number of feasible sites[7/] are available and that plant economies are such that multi-plant

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7/ Feasible sites are determined not only on the basis of physical attributes but also on the basis of security. Plants will locate together for safety reasons when markets or transportation is not assured when they would not otherwise.

sites provide both spatial efficiency and competition. Also possible, is duplication of plants at one site lead to high cost for all plants. A single plant, however, leaves the customer confronted by a monopolist (Bresler, p. 153). In such a case there is a trade-off or conflict between efficient market areas and competition which maintains pricing efficiency.

Because a cost approach is employed to address the question of how many delivery points are required there are some major theoretical limitations in the study. As pointed out there is a potential trade-off between cost saving market areas and competition. It has been assumed that technical efficiency is attainable without regard for the response of individual firms to that situation. There are in fact many possible courses of action open, particularly at country elevator points. The opportunity to exploit monopoly power at an individual location exists on the service side of operations in grain collection since tariffs have been strictly and uniformly applied to all locations. Some flexibility will be incorporated in the analytical model to cope with this theoretical limitation.

CHAPTER IV

ANALYTICAL FRAMEWORK

4.1 Introduction

The purpose of this chapter is to develop an analytical framework useful in determining the cost of grain handling and transportation. Considerations include several sets of circumstances that vary the level and location of the five basic components of the system.

It is assumed that plant costs are related to size and volume within the study area and not to specific locations. Trucking and road costs increase as plant sites decrease. Conversely, rail costs decrease with fewer delivery points. Elevators exhibit economies of scale and utilization with fewer locations. Fewer locations and higher utilization result in increased farm storage.

The model attempts to incorporate theoretical efficiencies related to plant size, use and location. A major challenge in the development of the model was to generate sufficient internal flexibility to cope with several technical and data limitations outlined at the end of this chapter.

4.2 An Operational Model

Lefeber (Lefeber, 1958) developed a procedure for explaining the location of economic activity which could readily be applied to practical problems. Assuming a given number of fixed locations for activity rather than a uniform plane, a 'programming' approach could be applied to the problem. Making the assumptions that costs are linear and divisible a unique solution may be found using a Linear Programming framework.

Each location is endowed with a specific level of resources some of which are transportable at a cost while others are fixed at their origins. Each location can produce, consume, or both. Thus, optimal resource allocation, production, and commodity distribution over space is derived given the supply of resources, demand, and costs for manufacturing and transportation. Lefeber's approach provided a background for a number of empirical studies in plant location.

Later, J.F. Stollsteimer (Stollsteimer, 1963) developed a workable procedure for determining the number, size, and location of plants based on assembly and processing costs. The questions he set out to answer were the following.

> "How many plants should we have?
> Where should our plants be located?
> How large should each plant be?
> Where should the raw material processed in each plant be obtained?
> What customers should be serviced by each plant?"
> (Stollsteimer, p. 631)

Stollsteimer's technique provided an important step in answering these questions. The requirements for the Stollsteimer solution are: 1) assume a designated number of points at which supplies are located and/or at which plants may be established, 2) specify a transportation cost function, 3) specify a processing cost function and, 4) specify supply and demand for each site.

The objective of the Stollsteimer model is to minimize total cost by searching all combinations of <u>numbers</u> and <u>locations</u> for the unique least cost combination. The procedure is carried out in stages. For each number of sites a search is undertaken for the combination which provides the lowest transportation cost. Plant costs are minimized for the volumes assembled and added to assembly costs giving a minimum cost for that number of plants[1/]. The process is repeated for each number of plants until a global minimum is found.

The number and location of plants is determined by assembly cost minimization. Plant size follows directly which implies that for whatever volume of inputs assembled at a point there exists a feasible plant size.

There are some difficulties associated with the Stollsteimer procedure. The complete elimination approach to the search for cost minimization is computationally prohibitive for large problems. In an analysis of an industry where facilities are already in place the value of 'what is' is not recognized and as well any number of institutional constraints restricting action in the industry are also not recognized.

4.3 The Analytical Design

A modified version of the Stollsteimer technique was used as the basis for addressing the grain collection problem. If an elevator is viewed as a plant and a grain delivery point as the processing site the objective is to minimize assembly, processing, and distribution costs associated with grain handling and transportation in a designated area.

A set of points was specified for elevators. These are the grain delivery points as they existed August 1, 1974 in the study area. Grain

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1/ Stollsteimer did not include distribution costs in his application. They have been incorporated by others (Warrack and Fletcher, 1970) following the technique.

supplies were determined on the basis of the most recent ten year average handlings at each point. Demand was set equal to supply and was divided equally between the major ports of Thunder Bay and Vancouver. The appropriate costs for the system were divided into 5 separate components: (1) Assembly cost, represented by the cost of trucking grain from farms to elevator, (2) Processing costs, represented by elevator costs for storing and handling grain, (3) Distribution costs, associated with the cost of rail shipment of grain from country elevator to port terminal elevators, (4) The cost of farm storage, included as a separate component required to store the volume of grain in excess of the capacity of elevators, and (5) Road costs over which grain is trucked, not included in direct assembly cost because of problems associated with changing routes and volumes.

Once the cost functions are specified the problem is solved in stages. A matrix of assembly costs from each point to all other points is searched for the minimum for a specified number of points. This establishes the location pattern determining both location and where supplies will be obtained for each. For the volume assembled at each site an elevator cost function is applied which gives the cost and appropriate plant size. Distribution follows from the location of sites with known supplies and port terminal locations with given requirements from each site. Grain shipments are assigned constant, equal proportions from each plant location to each port terminal[2/].

[2/] The division of grain between ports is an approximation for the total area being considered. The separation in fact may vary from one site to another depending on the mix of grain produced. However, this information would unduly complicate already detailed data requirements. The regional split was applied to each point individually.

The delivery pattern and supplies on each route provide the information required to calculate road costs. Finally, farm storage costs are calculated for the capacity required (as defined by total deliveries) in excess of that provided at elevator points.

Summation of the costs gives the total system cost for a specified number of sites and the location patterns under consideration. The process is repeated for each number of sites considered and for all location patterns for any specific number of sites. The global minimum found in the search will provide the answer to the questions (1) how many plants, (2) where, (3) how large, (4) who is to be served, and (5) from where?

4.4 The Algebraic Expression of the Model

Given that supply and demand conditions are known and the location pattern and number of sites are variable, the problem can be expressed in the following manner:

$$
\begin{aligned}
\min_{(j,\ Lp)} TC = & \sum_{i=1}^{I} \sum_{j=1}^{J} TRC_{ij} \cdot Q_{ij}/Lp \\
& + \sum_{i=1}^{I} \sum_{j=1}^{J} RC_{ij} \cdot Q_{ij}/Lp \\
& + \sum_{j=1}^{J} ELC_j \cdot Q_j/Lp \\
& + FSC \left(\sum_{i=1}^{I} Q_i - \sum_{j=1}^{J} C_j \right) /Lp \\
& + \sum_{j=1}^{J} \sum_{k=1}^{K} RRC_{jk} \cdot Q_{jk}/Lp \qquad (4.1)
\end{aligned}
$$

where:

TC = Total Cost with respect to the number of elevator points (j) and their location pattern (Lp),

i = sources of grain,

j = destination for grain at which elevators may be located,

Q_{ij} = quantity moved from source i to destination j,

TRC_{ij} = cost of transportation by truck from i to j per unit Q,

LP = the location pattern of j elevator points, which is one of the possible combinations of j points.

RC_{ij} = road cost from source i to destination j per unit Q,

ELC_j = elevator cost at site j per unit Q assembled there,

FSC = farm storage cost

Q_i = deliverable quantities of grain from i locations,

C_j = capacity of elevators at j sites to store grain,

RRC_{jk} = cost of moving grain by rail from elevator points j to port terminals k per unit Q.

Q_{jk} = quantity moved from each elevator point to terminals.

subject to:

$$\sum_{i=1}^{I} Q_i = \sum_{j=1}^{J} Q_j = \sum_{k=1}^{k} Q_k \geq 0$$

4.5 The Estimation Technique

The application of the Stollsteimer technique that requires the complete elimination approach, is only computationally feasible for small problems. For example, computing all combinations of 50 sites would take one year's work for a computer (Warrack and Fletcher, p. 482). Warrack and Fletcher developed two suboptimal search techniques for solving this problem. The iterative expansion approach (IEXPA) and the iterative elimination approach (IELMA). Using IELMA all sites are considered, then all but one, etc. When a site is eliminated on two successive iterations it is no longer considered. Using IEXPA, plant sites are chosen one at a time but always with reference to those previously chosen. IEXPA is the technique used in this analysis because it is cheaper to compute and the results are comparable for the two approaches (Warrack and Fletcher, p. 500).

4.5.1 Stage #1 (Assembly of Grain at Elevator Points)

Plant sites and supplies to each of them are based on 1974 conditions. When all sites are operational in the model grain moves within the local area to each point. When a point is closed the grain from it is transported to the nearest open point[4/]. The specific boundaries for each point are not specified except in so far as the average distance from farm to each point is known. It is assumed that grain is hauled to the nearest point when all are open and when one is closed to the next

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[4/] There is no distribution of deliveries from one closed point among the open ones because as the model searches for more points a single supply could be split a number of ways each time generating a prohibitive number of calculations.

nearest point.

Estimation of the assembly cost function requires a mileage matrix from each to every point. Each point is described by a set of co-ordinates and the distance between is calculated (Appendix F, p. 164). The distance within the area of each point (internal distance) is the farm delivery distances of each point in 1974. The result is a symmetric matrix (183 x 183) which gives the internal distance on the main diagonal and the distance between points in the off diagonal elements (Table 4.1).

Table 4.1

Mileage Matrix

	Source					
Destination	1	2	3	4	5	6
1	4					
2	9	8				
3	16	6	5			
4	22	12	6	5		
5	7	5	12	19	3	
6	11	7	14	21	4	4

Source: Hypothetical 6 point example

The volume of grain in the area around each point is known so the truck cost function (Appendix G.1) is applied to the mileage matrix which results in an assembly cost matrix (Table 4.2).

Table 4.2

Assembly Cost Matrix

Destination/Source $(000)

Point	1	2	3	4	5	6	Sum
1	12.3	71.5	32.9	38.7	7.4	10.1	172.9
2	18.6	59.0	24.4	31.6	6.4	8.8	148.8
3	22.6	67.0	19.8	25.5	8.9	11.0	154.8
4	25.2	77.5	24.4	20.5	10.4	12.6	170.6
5	17.2	65.7	30.0	36.9	4.8	7.4	162.0
6	19.9	68.1	31.5	38.1	6.2	6.3	170.1

Source: Hypothetical 6 point example

The selection procedure begins by considering a single point. The first site selected would be the minimum sum row in the assembly cost matrix. For the example, in Table 4.2, the first point selected would be point 2, providing the least cost. The second point chosen is the one which leads to the maximum saving in assembly cost, given point 2 was already chosen. In the example point 3 would be selected. In the selection procedure a minimum cost row vector is established which contains the minimum cost cells of points in the solution. For example, when points 2 and 3 have been selected the vector would be as follows:

18.6 59.0 19.8 25.5 6.4 8.8

The third point chosen is 1 because it gave the maximum saving in assembly costs when compared to the minimum cost row vector. When all points are considered the search terminates with assembly cost at a minimum and the values in the vector of minimum costs corresponding to the main diagonal of the assembly cost matrix. When less than the total number of points are operational there is additional assembly costs to move grain to points in the solution. The increase in costs for closed points is presented for the example where points 2 and 3 are open (Table 4.3) to demonstrate the implications for particular locations.

Table 4.3

Increased Cost for Assembly When Points Are Closed
$(000)

Point 1 hauls to:	Point 2, added cost = 6.3,	increase = 51.2%
Point 4 hauls to:	Point 3, added cost = 5.0,	increase = 24.4%
Point 5 hauls to:	Point 2, added cost = 1.6,	increase = 33.3%
Point 6 hauls to:	Point 2, added cost = 2.5,	increase = 39.7%

Source: Hypothetical 6 point example

4.5.2 Stage #2 (Road Costs Due to Trucking Grain)(Appendix, G.2)

The estimation of road costs is accomplished by means of load factor and truck size matrices (See Tables 4.4, 4.5) which are generated as by-products when calculating the assembly cost matrix. Dividing the total deliveries from each source by the corresponding truck size will develop the number of truck loads for each route. The distance travelled for each route is calculated when generating the assembly cost matrix. The total road cost for a single source-destination combination is given by:

$$RC = L.F. \times \text{Loads} \times \text{miles} \times \text{cost/mile} \qquad (4.2)$$

where:

RC = total road cost,

L.F. = weighted average load factor for the route.

Summing the road costs for all operational routes provides the total road costs for grain for the area.

Table 4.4

Load Factor Matrix (1 = 18,000 lb. axle load)

Destination \ Source	1	2	3	4	5	6
1	0.78	1.38	1.51	1.68	1.16	1.38
2	1.33	1.12	1.11	1.48	1.01	1.18
3	1.55	1.29	0.82	1.21	1.40	1.48
4	1.66	1.48	1.11	0.91	1.59	1.62
5	1.22	1.27	1.40	1.63	.62	.95
6	1.41	1.31	1.46	1.66	.91	.74

Source: Hypothetical 6 point example

Table 4.5

Truck Size Matrix (bushels)

Destination \ Source	1	2	3	4	5	6
1	190	234	244	256	218	234
2	231	215	214	242	207	220
3	247	228	192	223	236	241
4	255	241	214	201	249	252
5	223	226	235	253	177	203
6	235	230	240	255	200	186

Source: Hypothetical 6 point example

4.5.3 Stage #3 (Cost of Country Elevator Operations)

Elevator cost estimation occurs after the deliveries to open points are determined in the assembly cost stage. A direct calculation from the elevator cost function is one alternative means of determining elevator costs (Appendix G.3). Minimization of the elevator cost is obtained by setting up the appropriate sized facility for given deliveries and an efficient or maximum handling to capacity ratio. Alternately, the facilities in existence can be costed. Grain assembled at each point is distributed among facilities based on their relative capacities. An option also exists by which the use of existing facilities can be limited.

Elevators at each point are listed in ascending age and descending size see Appendix B. Restricting two elevators to each delivery point for example leaves the newest and largest facilities for consideration in the estimation process. Elevators can also be ignored due to their age alone. For example, a limit of 40 years would eliminate from consideration all elevators in the area in excess of that age. Where no elevators at a point meet the age requirement a rebuild option may be specified, otherwise the delivery point is closed.

The final option available in dealing with elevators is a competitive vs. monopoly distinction when costing new facilities.[5/] A single facility at each point or two of equal size and handling are options.

[5/] The competitive option cost estimate will result in higher cost but it is included as it is of interest to determine a price paid for 'opposition' at a delivery point.

The competitive option is not available for any point where the grain assembled is less than 300,000 bushels.

4.5.4 Stage #4 (Estimation of Farm Storage Costs)

After the determination of the elevator configuration the estimation of farm storage cost follows readily (Appendix, G.4). The volume of grain delivered in the area is known as is the total capacity of all elevators in existence in 1974. The difference between deliveries and elevator capacity is the volume stored in existing farm facilities. Any reduction in storage space due to the closure of elevators or delivery points is added to farm storage costs and requires new facilities[6/].

4.5.5 Stage #5 (Railway Cost Estimation)

Railway costs (Appendix G.5) are determined once the delivery points are established. Costs are related to the number of points operating on a particular rail line segment and the grain density on the track. An alternate calculation is made in which a hypothetical improvement is assumed for rail lines (see Appendix G.4, p. 168 for details). The third method used is application of the Crow's Nest Pass Rates. When the Crow Rate option is used the rate from each point is applied to 1/2 the assembled grain to each terminal location.

4.5.6 System Cost

The total or system cost is the summation of trucking, roads

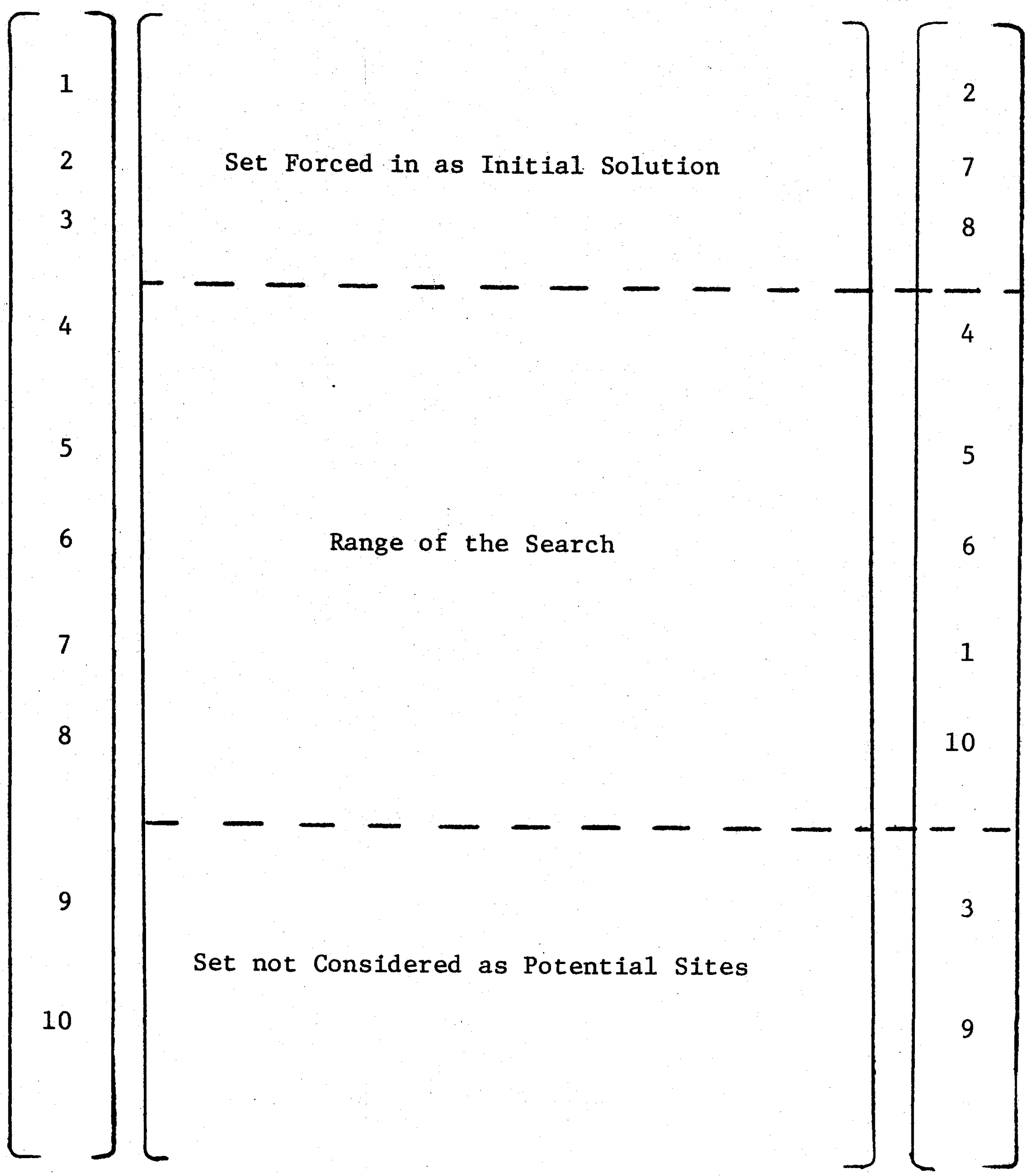
6/ If a farm storage cost was greater than commercial storage costs it would be appropriate to consider a commercial 'storage' system as opposed to a 'handling' system.

elevators, farm storage and rail costs for the number of points and location patterns considered. The estimation process is repeated for each added point until all are considered and a mininum cost number is found. Though only one set of conditions is summarized when calculating total cost, six sets of conditions are calculated and carried with the solution. Three rail cost options are calculated and two elevator options which in addition to the basic solution provides the six combinations.

4.6 Further Alterations to IEXPA Technique

It is recognized that a search procedure such as this one which arrives at a suboptimal solution is subject to criticism (Tosterud, pp. 77-78). The initial point selected, based on assembly cost, is the weighted geographic center of production for the area which may not be an appropriate site for any number of reasons not considered in the model. With this in mind three further alterations are made to the search technique. First, a set of points can be forced into the solution as an initial set of conditions. Second, any set of points can be forced out of the solution or points can be forced out either by closure of a rail line or individually due to the age of their facilities (see Figure 4.1). When the above options are used a system cost is calculated initially for the 'forced in' set. The search continues in the normal way selecting points one at a time from the allowed range. When all are selected accepting the 'forced out' set the system cost is calculated and termination occurs. With the number of conditions considered and the options available the model is flexible for estimating grain collection costs under a wide range of circumstances and

Figure 4.1 Partitioned Assembly Matrix



Source: Hypothetical 10 point example

policy alternatives.

4.7 Alternatives Considered in Grain Collection

An initial set of conditions are established which represent the grain collection system as it existed in 1974. The 1974 configuration is the base used to compare a number of possible changes in the system for which cost efficiencies may exist.

The major change considered in this research is the number and location of grain delivery points. A second change involves altering the method of dealing with elevators, once points are selected. Other considerations are abandonment of branch lines, closure of small elevator points, and selection of points where large scale commitments have already been made. In all cases, the cost of railways is carried in three forms to demonstrate its effect. In each case the separate components are identified by their levels in relation to changing the number of delivery points in the system.

There is a total of 10 cases considered with represent varying combinations of the criteria described. A limit of 178 delivery points are considered for the area. Five of the 183 points in the area are duplicate and considered as a single point, though served by two rail lines.

In some cases a further 31 are forced out of the set to be considered. These are small points closed since 1974 which will help to evaluate the saving to the system resulting from consolidation. In two cases a number of large towns (17) and large delivery points were forced into the solution initially. These represent centers where there are substantial existing commitments. Also in two cases a number of rail branch lines (13) were abandoned which lead to the closure of delivery points on those lines. These cases will help to demonstrate the effect of rail line abandonment on the system. A crop index of 1.25 was assumed in one case to determine the effect of changing production levels. A 25% increase in deliveries is about equal to the recent delivery increase over the 10 year average used in the study.

The age criterion was applied in some cases. In one case all elevators were costed at new price levels in 1974, in two others elevators greater than 40 years were closed. In one of these cases this lead to closing the delivery point when all were greater than 40 years, in the other case the points were rebuilt. In the remaining options no age limit was enforced.

An alternate form of consolidation to closure of delivery points is to avoid duplication. There are up to seven elevators in existence at any one point, these are allowed to operate under most conditions, under two options a limit of two and one elevator were allowed to remain in the system. In both cases the newest and largest facilities are the ones allowed to remain in operation.

In all cases the number of locations for delivery points is a variable. In some cases a set of points is forced in and/or a set forced out so the search is confined to a set less than 178.

4.8 Limitation of the Model

There are some data and conceptual limitations that should be clearly understood so the model and its application can be evaluated realistically.

First, a cost approach is taken in this analysis which eliminates market, service and community considerations. The market is assumed to be equally well served under all conditions in the study. Technical efficiency, which is the focus of this model, may never be achieved. For example, a competitive environment for elevator operations in the past has resulted in duplication. If duplication is inconsistent with technical efficiency the policy changes required to implement the efficient system are not addressed.

Given the cost approach to the grain collection problem there are some components omitted. The cost of trucking from field to farm storage was omitted (Figure 1.1) because sufficient information was not available. Also, all components from the port terminal to the consumer were not considered. They are part of the system and undoubtedly have an impact on the nature of the system from farm to port.

Selection of grain delivery points is based on the truck cost matrix rather than simultaneous consideration of all cost components. The IEXPA technique ignores many potential location patterns for grain delivery points. These factors combine to provide a set of sub-optimal solutions in this analysis that may vary from the optimal solution by an unknown quantity. However, the model does confront a number of decision variables that must be solved before it becomes realistic to consider the optimal solution. Also, as mentioned in Section 4.5 an optimal solution to the grain collection problem is prohibitive given the time and financial constraints of this project.

There are important data and conceptual limitations for road and railroad components. The cost for roads was based on a given surface and level of traffic. In fact, surface and traffic are variable and should be examined on an individual route basis. Costs for roads only maintain them and do not account for any upgrading that may be required. The information available on railway costs was limited. The rail cost function specified in Appendix G.4 implies (aside from inflation) that railways could continue to operate lines in their present condition given the capital cost allowance used. In fact some lines may not be able to function much longer at their present minimum upkeep level.

The rail lines and delivery points used in the study are based on the existing system in the study area. There may be another rail network and set of delivery points that could be more strategically located. The drawing distance for grain around each delivery point reflects 1974 patterns which do not correspond exactly to the boundaries if they were defined by minimum trucking distance. When a grain delivery point is closed all the grain from the area of the closed point is moved to the nearest open one. In practice deliveries would likely be divided among two or more open points.

Time is ignored in the model. Any change in costs due, for example, to changing seasonal delivery patterns are not accounted for. In the longer term any nonproportional inflation rate could alter the results of an application of the model. Because of data limitations this problem is not addressed.

CHAPTER V

RESULTS

5.1 Introduction

A computer program was developed to aid in calculation of the cost of grain collection for the study area.[1/] Ten separate calculations were made using the program. These calculations varied according to assumptions concerning: 1) the number of delivery points that could be selected, 2) the use of existing elevators based on age and duplication of service, 3) the maximum allowed handling/capacity ratio, 4) the rail lines in use, and the volume of grain delivered.

In each of the ten cases, the system cost is presented for two separate railway cost options. The Crow's Nest Pass rate is the first option[2/]. The second option is based on a function (Appendix G, p. 173) which uses cost information presented to the C.T.C. by the railways.[3/]

Case #1 This case presents the cost calculations for grain collection based on the facilities in the study area in 1974. There were 178 delivery points, all elevators and all railways were assumed to operate. The calculations for 178 points under these conditions provide the benchmark against which all other case calculations are compared.

Case #2 This calculation of the system's cost is similar in all respects to Case #1 except 31 small delivery points were not considered as

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1/ For a detailed explanation of the computer program see Department of Agricultural Economics, University of Saskatchewan, Technical Bulletin, "A Computer Program for Determining the Optimum Number and Location of Grain Delivery Points in a Selected Area of Western Canada"

2/ This option is referred to as the 'Crow' option in this chapter.

3/ This option is referred to as the 'cost' option in this chapter.

potential delivery sites. These points are the ones that have been closed since 1974. Costs for Case #2 will indicate how much has been saved from 31 delivery point closures.

Case #3 In this case all elevators in the study area greater than 40 years old were not used. An individual delivery point was closed when no elevators at it could meet the age criterion. All 178 points were considered. Comparison with Case #1 will indicate whether or not the natural attrition of elevators will lead to lower cost.

Case #4 This case is similar to Case #3, however, where no elevators at a delivery point meet the 40 year age requirement the point can still be selected for delivery through use of new facilities. Comparison of Cases #3 and #4 will indicate whether the age of facilities is sufficient reason to close delivery points or whether replacement is feasible.

Case #5 In this case inefficient use of elevators as expressed in the handling/capacity ratio is assumed. This is a major characteristic of the grain collection system. A maximum h/c ratio for this calculation is 3:1 which compares with 6:1 the standard in all other cases. Aside from the handling to capacity ratio this case is the same as Case #4.

Case #6 In the cases described so far use of at least some existing elevators was assumed. In this case no existing elevators are used. All 178 points are potential delivery sites. For the sites selected the cost of handling and storing grain in elevators is taken as if all facilities were new in 1974. This case compared to the benchmark will indicate whether a new set of elevators efficiently located and operated will provide lower cost grain collection.

Case #7 In this case only one existing elevator was considered for each delivery point[4/]. The one used was in all cases the newest or largest where two were approximately the same age. All 178 points were considered and no limit was placed on the operable age of an elevator. Spatial dispersion is forced on the system in this manner to determine the impact of reducing the number of elevators as distinct from reducing the number of delivery points.

Case #8 In this case a maximum of two existing elevators are considered for each delivery point. In all other respects this calculation of the system's cost is identical to Case #7. A comparison between these two cases will indicate the minimum added cost of grain collection arising from 'opposition' at individual delivery points.

Case #9 This case attempts to deal to a greater degree with existing commitments to the collection system. First, 17 delivery points are forced as an initial solution. They are either; 1) the large towns and cities in the study area, or 2) points which have handled, over the ten year average, one million bushels or greater. Second, 13 rail lines were assumed closed. These lines were those in the area that; a) are designated as branch lines <u>and</u> b) on which no point was forced into the initial set. Third, the 31 points closed since 1974 were excluded from the set of potential sites[5/].

4/ In this and all cases where facilities are not used or a delivery point does not enter the solution no cost is attached to nonuse of a facility.

5/ In this case the decisions on which points to force initially and which rail lines to close are somewhat arbitrary and as such are designed as an example. The case does not constitute a recommendation.

Case #10 This case is a replication of Case #9 with one exception. The deliveries of grain in the area were assumed at a level 25% greater than the ten year average for the study area (standard in the previous nine cases).

These ten cases by no means exhaust the possibilities for changing grain collection in the study area but they are representative of possibilities and will indicate the type of results to be expected in further applications.

5.2 Case #1 (Costs of Grain Collection in the Study Area - 1974)

The cost of grain handling and transportation for the study area based on 1974 costs was 49.37 million dollars for 80 million bushels of grain delivered to country elevators. This represents a cost of 61.7¢ per bushel based on the assumptions that all licensed elevators were operating, all 178 delivery points were open and the railway cost (as distinct from railway rate) was used for the calculation. The alternate calculation using Crow rate lead to a cost of 33.4 million dollars or 41.4¢ per bushel. These two calculations are used as benchmark figures against which other calculations are compared for savings.

The total cost figures 61.7¢ (41.4¢) were made up of rail cost (rate) 33.7¢ (13.5¢), elevator cost 15.3¢, trucking cost 5.5¢, road cost 2.4¢ and farm storage cost 4.9¢.

Grain collection costs could be reduced with fewer than 178 delivery points. When the system cost was calculated using railway cost 21 delivery points were optimum. The total cost per bushel was 57.2¢, a saving of 4.5¢ per bushel when compared to the 1974 system. When the Crow rate was used 80 points resulted in least cost (Table 5.1) at 40.5¢

per bushel, a saving of 0.9¢ per bushel.

Table 5.1

Estimated Grain Collection Costs for the Study Area Assuming all 1974 Delivery Points and Elevators are Available for Operation.

$(000,000)

Points	F.S.	TR.	RD.	EL.	Rail #1	Rail #2	Tot #1	Tot #2[2/]
2	6.33	9.12	8.38	7.39	10.30	20.00	41.50	51.22
10	6.33	6.40	5.66	7.21	10.42	21.05	36.02	46.65
21	6.32	5.69	4.35	7.16	10.48	22.22	34.00	45.74[3/]
40	6.16	5.17	3.18	7.45	10.60	24.96	32.56	46.92
60	5.70	4.89	2.66	8.39	10.72	26.63	32.36	48.27
80	5.29	4.72	2.40	9.23	10.72	26.73	32.36[3/]	48.37
100	4.84	4.60	2.21	10.14	10.74	26.80	32.53	48.59
120	4.56	4.51	2.08	10.80	10.73	26.97	32.68	48.92
140	4.31	4.45	1.99	11.36	10.74	27.07	32.85	49.18
160	4.13	4.41	1.94	11.79	10.75	27.10	33.02	49.37
178[1/]	3.88	4.39	1.92	12.21	10.74	26.97	33.14	49.37

[1/] Indicates the cost of grain collection for the area with the system as it existed in 1974.

[2/] Points = number of delivery points
F.S. = total cost of farm storage in the study area
TR. = trucking cost
EL. = elevator cost
Rail #1 = rail cost assuming the Crow's Nest Rate
Rail #2 = rail cost assuming cost function (Appendix G, p. 173).
Tot #1 = total system cost using Rail #1
Tot #2 = total system cost using Rail #2

[3/] Minimum total cost

Source: Calculated from optimal solution to Case #1.

The addition to total cost when 157 points are operated in addition to the 21 is 7.4% and 2.4% where 98 are added to the 80 selected in the alternate calculation. Figure 5.1, p.61 demonstrates graphically the nature of change in total cost when the number of delivery points is varied.

The minimum cost number of points produces some major shifts among cost components (Figure 5.2, p.62). With the reduction in the number of delivery points the cost burden moves from elevator and railway to trucking, storage, and road components. Table 5.2 indicates the percentage change in each component from the 1974 conditions.

Table 5.2

% Change in Cost Burden, Components and Total, (Case #1)

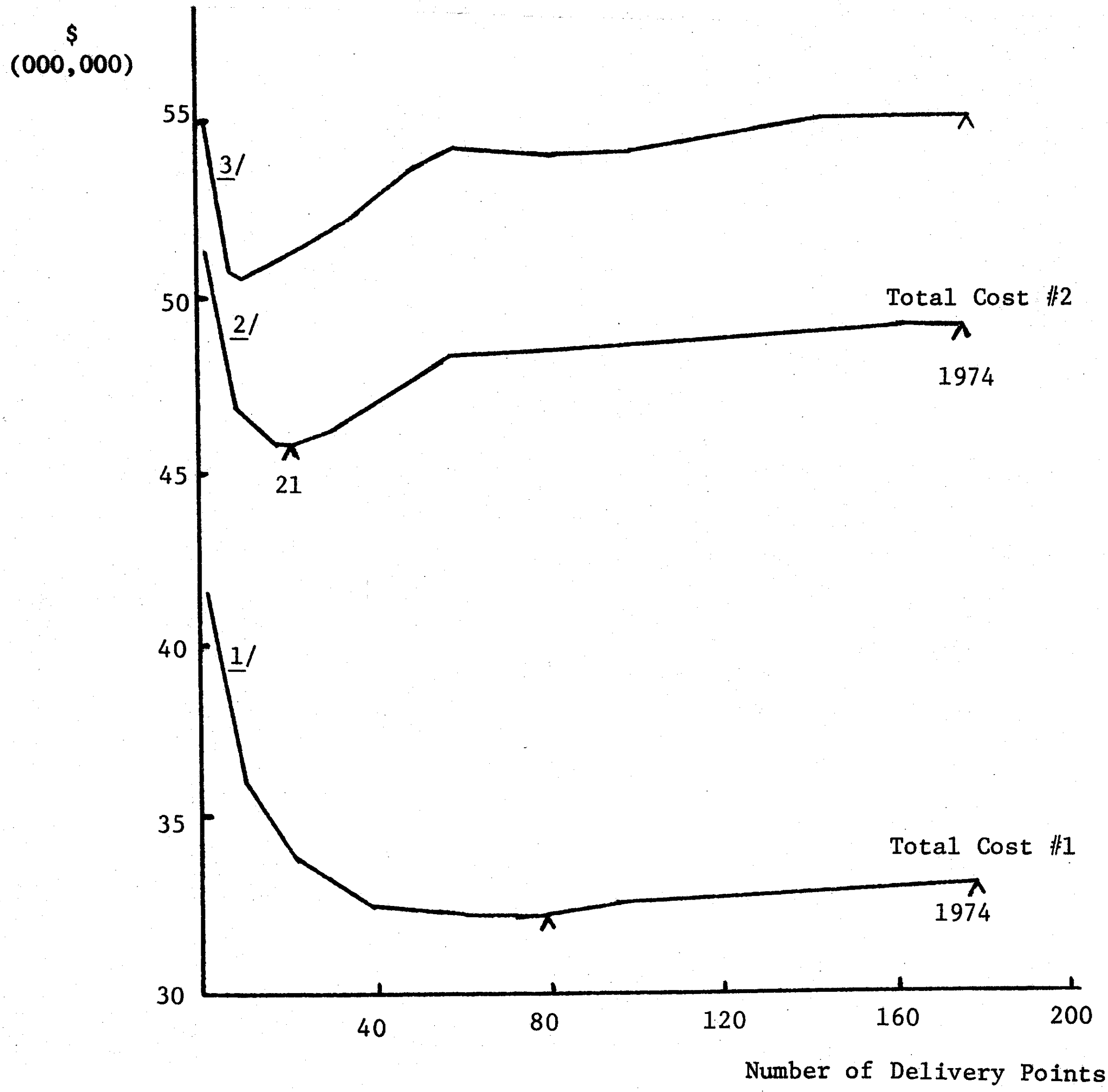
Component	Change (178 to 21 pts.)	Change (178 to 80 pts)
Farm Storage	+ 62.9%	+36.3%
Trucking	+ 29.6%	+ 7.5%
Roads	+121.4%	+25.0%
Elevators	- 41.4%	-24.4%
Railroads	- 17.6%	- 0.2%
Total	- 7.4%	- 2.4%

Source: Calculated from optimal solution to Case #1

The change in costs are not distributed evenly over all locations, as demonstrated by the delivery patterns for the 21 and 80 point solutions given in Figure 5.3 and 5.4.

Figure 5.1

Variation in Total Grain Collection Costs for the Study Area when the Number of Collection Points is Varied (Case #1)



1/ Collection costs assuming Crow rate.

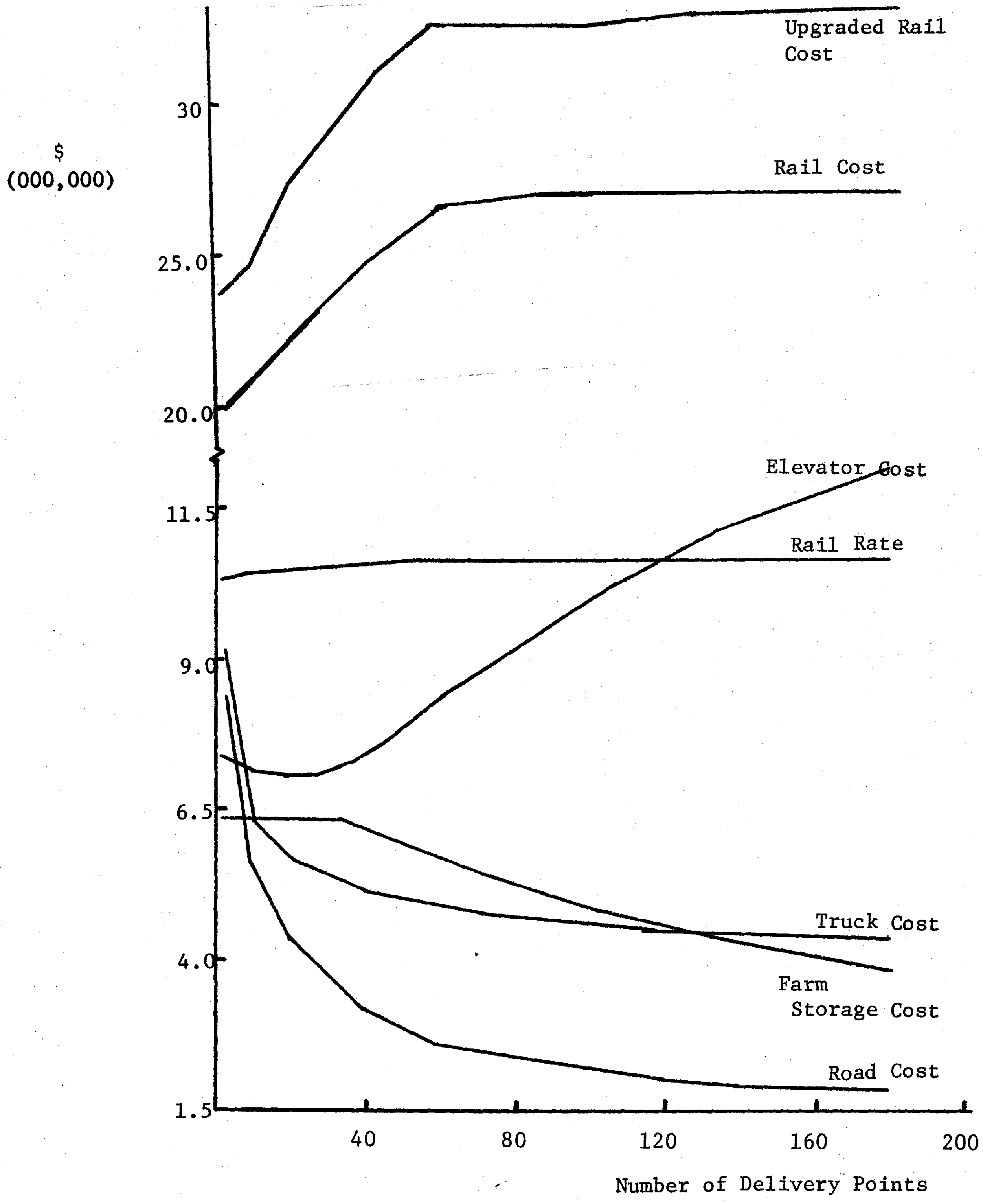
2/ Collections costs assume railway cost.

3/ Collection costs with upgrading of railways. (See Section 5.12, pp. 94-5).

Source: Calculated from optimal solution to Case #1.

Figure 5.2

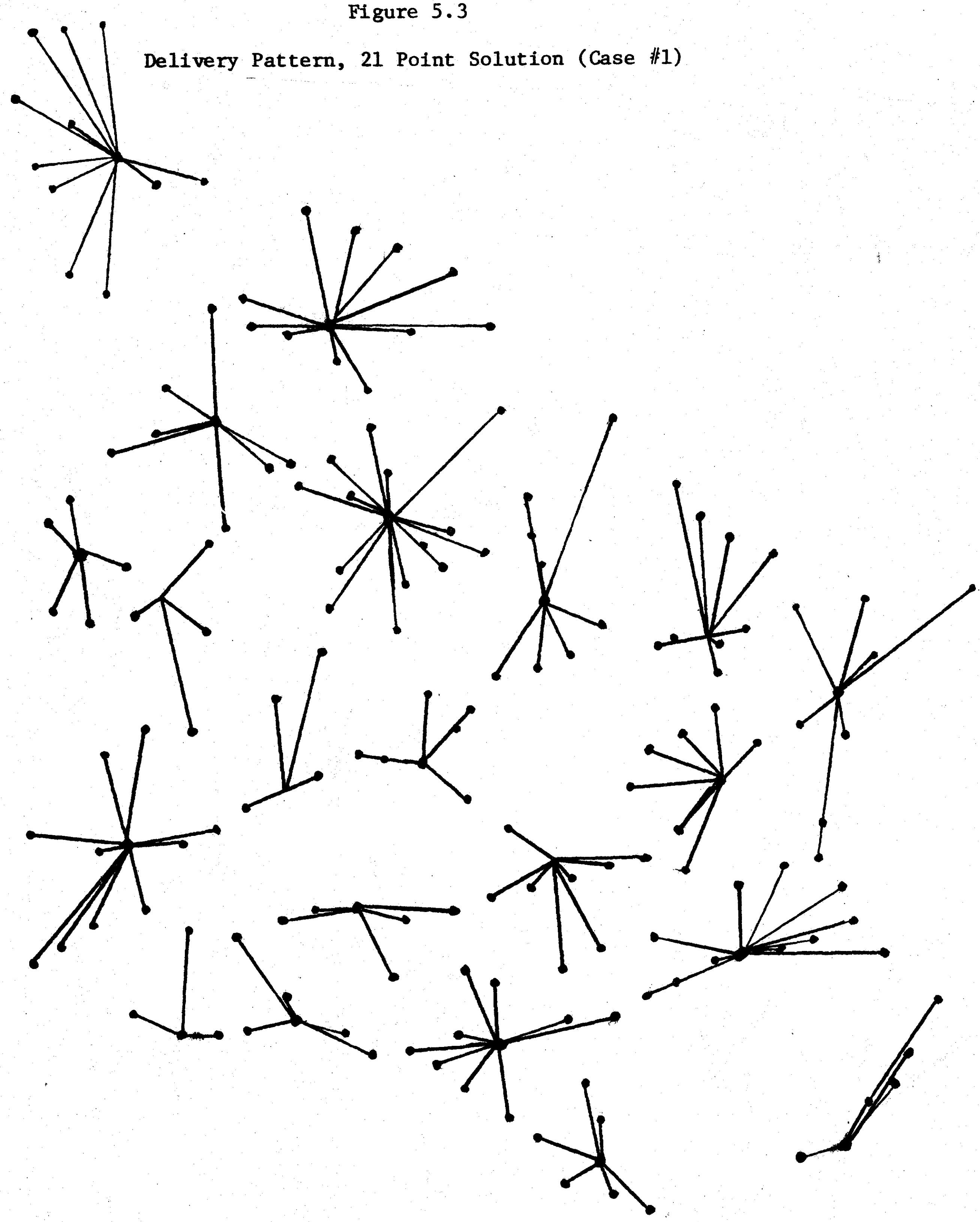
Variation in Component Costs when the Number of Collection Points is Varied (Case #1)



Source: Calculated from optimal solution to Case #1.

Figure 5.3

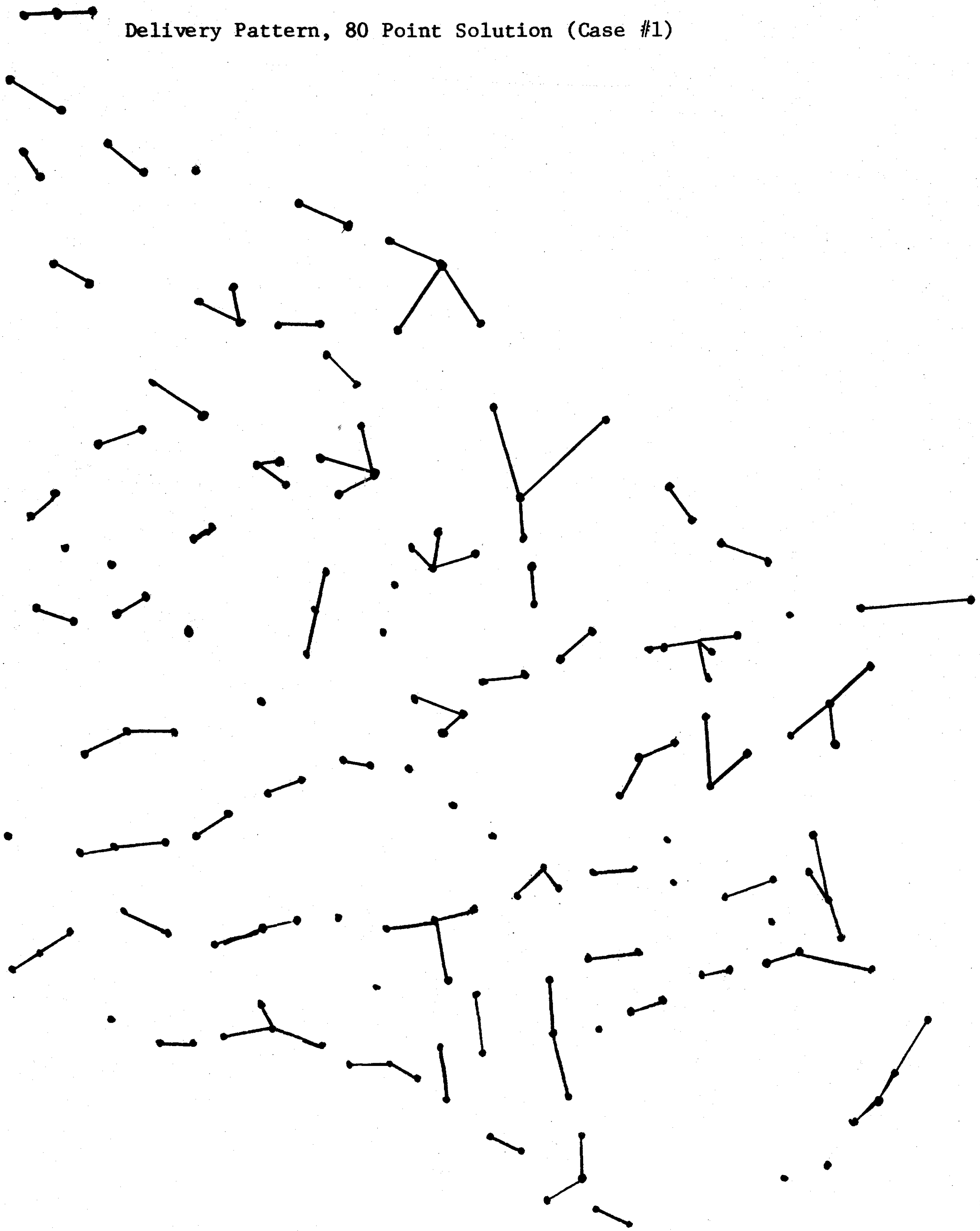
Delivery Pattern, 21 Point Solution (Case #1)



Source: Derived from optimal solution to Case #1.

Figure 5.4

Delivery Pattern, 80 Point Solution (Case #1)



Source: Derived from optimum solution to Case #1.

The change in grain delivery patterns resulting from centralized collection results in a nonproportional change in farm trucking costs. Taking the rail cost option for Case #1 no change in trucking cost was experienced for the 21 points that remained open. For the remaining 157 points the percent increase breaks down as follows: 1-20% (27 points), 21-40% (49 points), 41-60% (39 points), 61 - 80% (30 points) and 81% + (13 points).

Annual deliveries of grain to the 21 points would range from 2.4 to 6.1 million bushels. 8.67 million bushels of added elevator capacity would be required at those points to generate a 6:1 handling to capacity ratio as a maximum. In this case only one point had sufficient space and handled at less than 6:1.

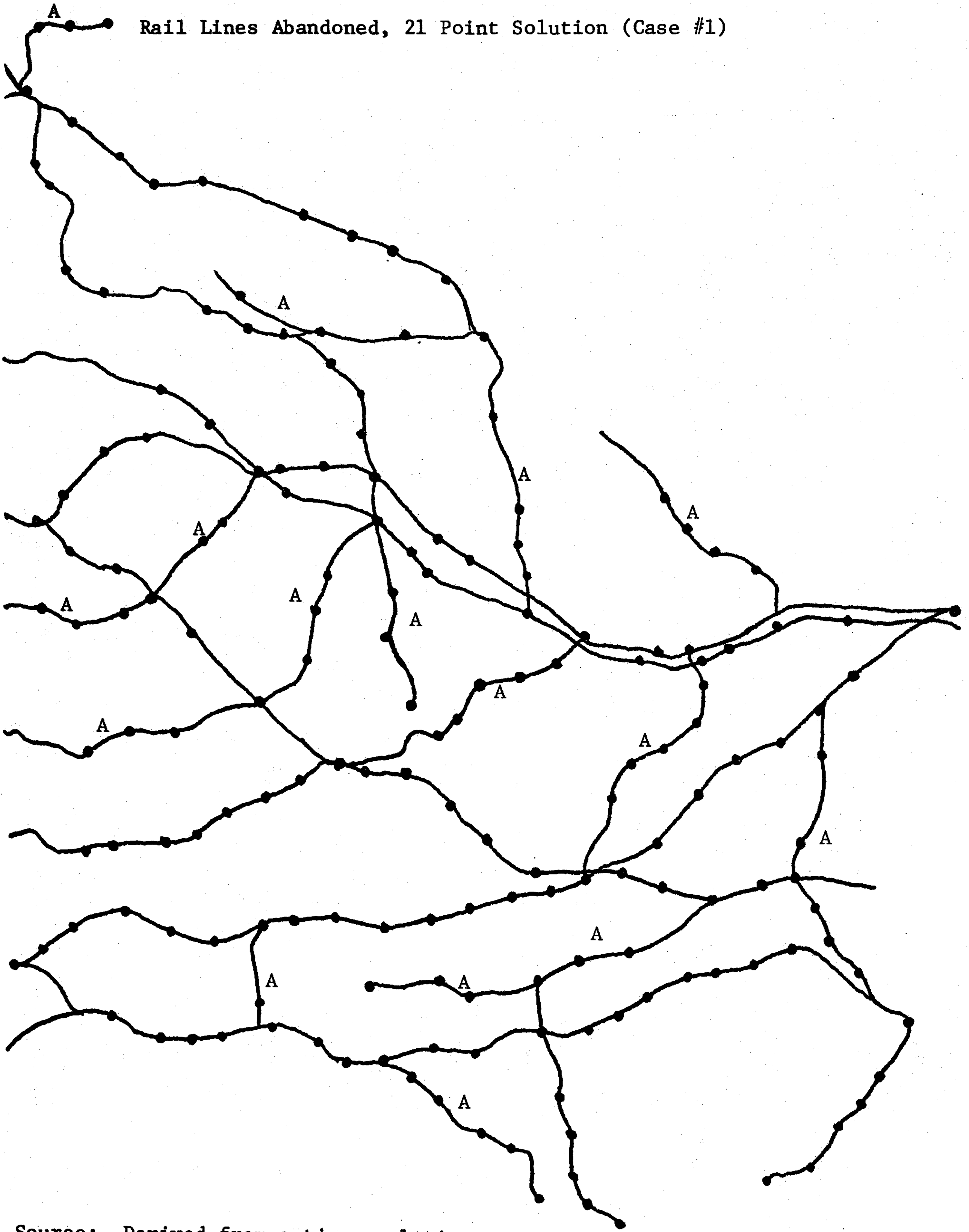
With the 21 point arrangement a number of the 27 rail segments located within the area had no open points, these lines were in effect abandoned. Figure 5.5 indicates with an A notation which lines these were. When the alternate estimate of the system was used leading to 80 points no rail segments were abandoned.

5.3 Case #2 (Effect of Delivery Point Closures Since 1974)

There were 31 delivery points closed in the study area since 1974 (Figure 5.6, p. 67). The cost of operating the remaining 147 points was 41.2¢ per bushel or 61.4¢ depending on whether the Crow rate or cost was included in the total. Closure of 31 small points saved 0.2¢ or 0.3¢ per bushel. This represents a decrease of 0.6% in total cost and a redistribution of costs among components as follows; farm storage +5.4%, trucking +1.4%, roads +4.2%, elevators

Figure 5.5

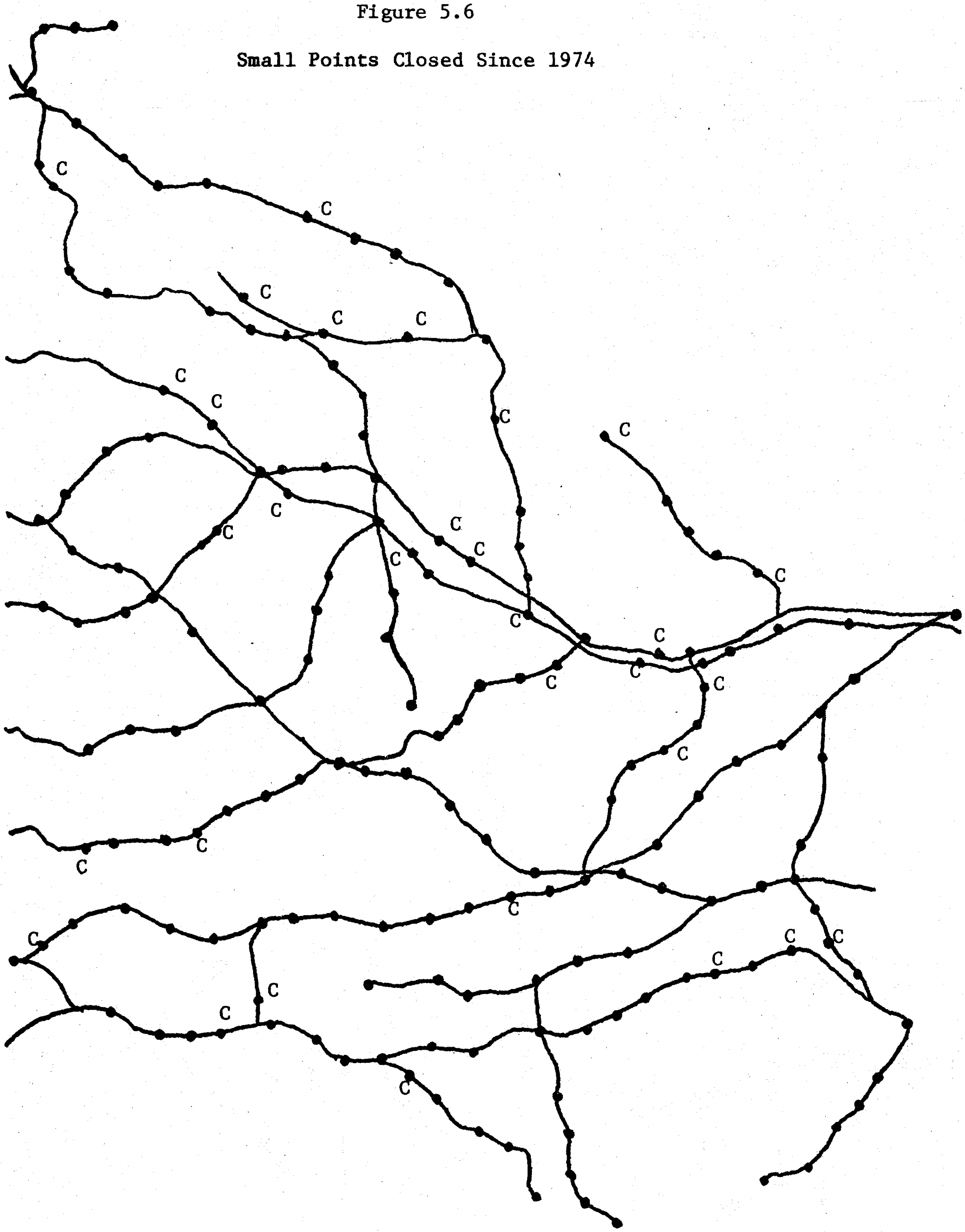
Rail Lines Abandoned, 21 Point Solution (Case #1)



Source: Derived from optimum solution to Case #1.

Figure 5.6

Small Points Closed Since 1974



Source: Canada Grains Council, Area 11 Study, Appendix IX, pp. 114-198.

-4.4% and railways -0.3%. Given that only 147 points were available for selection the minimum total cost (40.4¢ per bu.) for Case #2 was achieved at 60 points using the Crow rate option. When rail cost was used ten points provided minimum cost at 58.5¢ per bushel (Figure 5.7). The Crow rate option lead to a total cost identical to Case #1, the rail cost option in this case could not match the efficiency found in Case #1 (58.5¢ per bu. vs. 57.2¢ per bu.) where 21 rather than 10 points were optimal.

5.4 Case #3 (Closure of Elevators Older than 40 Years)

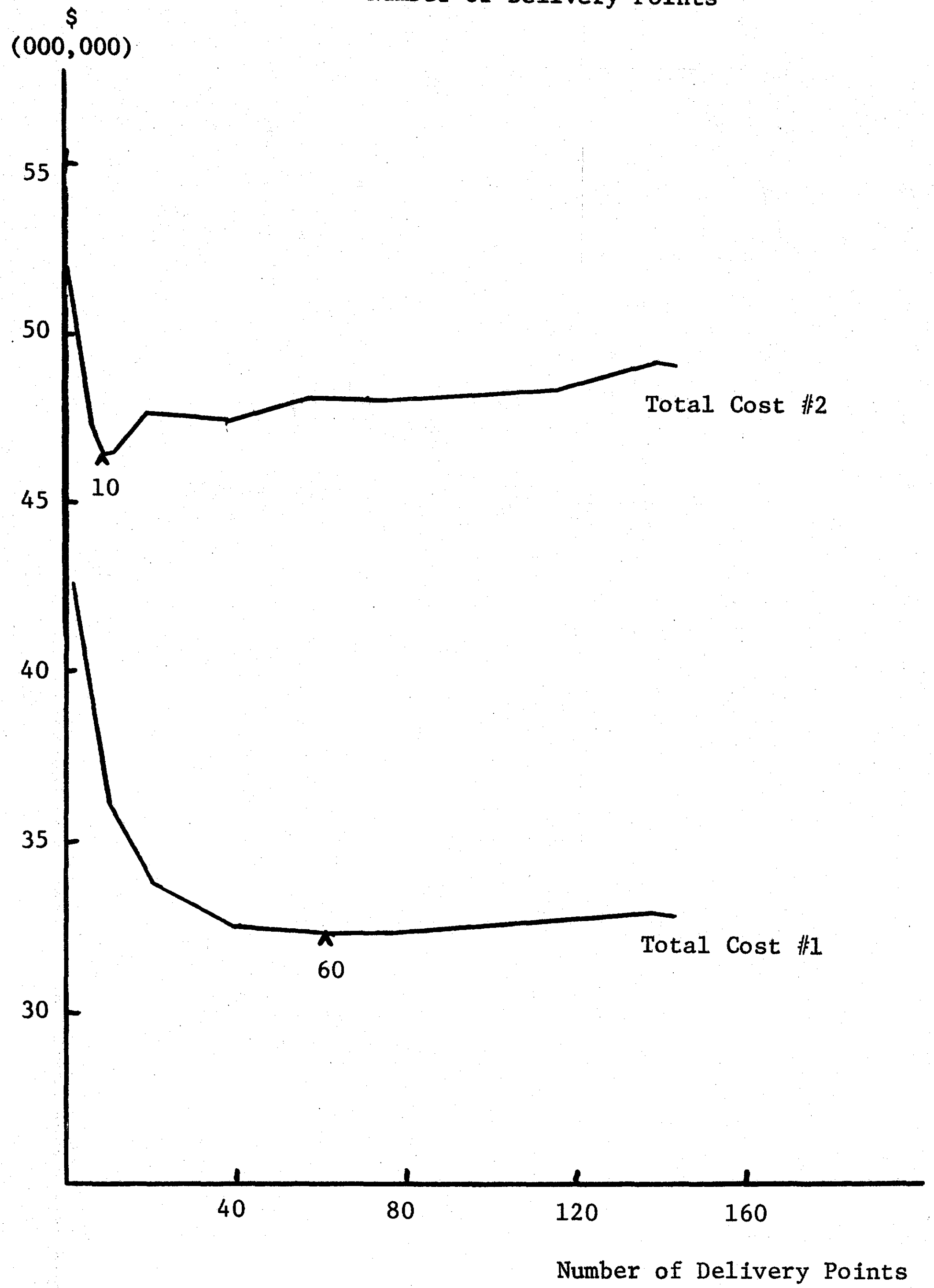
There are a large number of old elevators in the study area (Table 2.1). It was assumed that any elevator older than 40 years would be closed and that any delivery point, all of whose elevators were older than 40 years would also be closed. Elevators were constructed only at those points where new enough facilities already existed and where the remaining capacity was too small to handle grain at 6:1 or less.

Ninety-two of 178 points were closed due to the age criterion alone. The minimum cost number of points was 6 when the rail cost option was used. The number of points increased to 46 when the Crow rate was used (Table 5.3). The total cost figures represent a cost of 43.5 cents and 59.8 cents per bushel respectively. The costs at the minima are 2.6¢ and 3.0¢ higher when compared to the costs in Case #1 at 80 and 21 points where no restriction was placed on the use of existing facilities.

Though the change in total cost was modest there were some major

Figure 5.7

Change in Total Costs (Case #2) with Variation in Number of Delivery Points



Source: Derived from optimal solution to Case #2.

Table 5.3

Total Grain Collection Costs Assuming Only Elevators Less Than 40 Years Are Operated

Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2[1/]
2	6.57	9.14	8.36	7.48	10.30	20.00	41.85	51.55
6	6.49	7.05	6.44	7.84	10.42	20.00	38.24	47.82[2/]
10	6.40	6.43	5.79	8.15	10.45	21.59	37.22	48.36
20	6.24	5.78	4.49	8.81	10.48	23.34	35.80	48.66
40	5.97	5.19	3.34	9.78	10.62	24.64	34.90	48.82
46	5.65	5.16	3.27	10.10	10.65	25.04	34.86[2/]	49.22
60	5.64	4.97	2.83	11.05	10.69	25.56	35.18	50.05
80	5.35	4.88	2.68	12.21	10.71	25.82	35.83	50.94
86	5.18	4.87	2.67	12.47	10.71	25.59	35.90	50.78

[1/] See footnote [2/] Table 5.1 for explanation of the titles

[2/] Minimum system cost for Case #3

Source: Calculate from optimum solution to Case #3

offsetting adjustments observed in the cost arising from each of the individual components (Table 5.4).

When elevators in excess of 40 years are closed the number of delivery points was substantially reduced with little change in total costs at the efficient number of points (compared to those in Section

5.2). The component costs change markedly, particularly in the range where six points provide the optimum, costs are unstable (Figure 5.8, p. 72).

Table 5.4

Change in Cost Burden (Case #3)

Component	Change (178 to 46 pts.)	Change (178 to 6 pts.)
Farm Storage	+ 51.0%	+ 81.7%
Trucking	+ 16.2%	+ 46.7%
Roads	+ 58.3%	+235.4%
Elevators	- 17.3%	- 35.8%
Railways	- 2.0%	- 25.8%
Total	+ 4.9%	- 3.1%

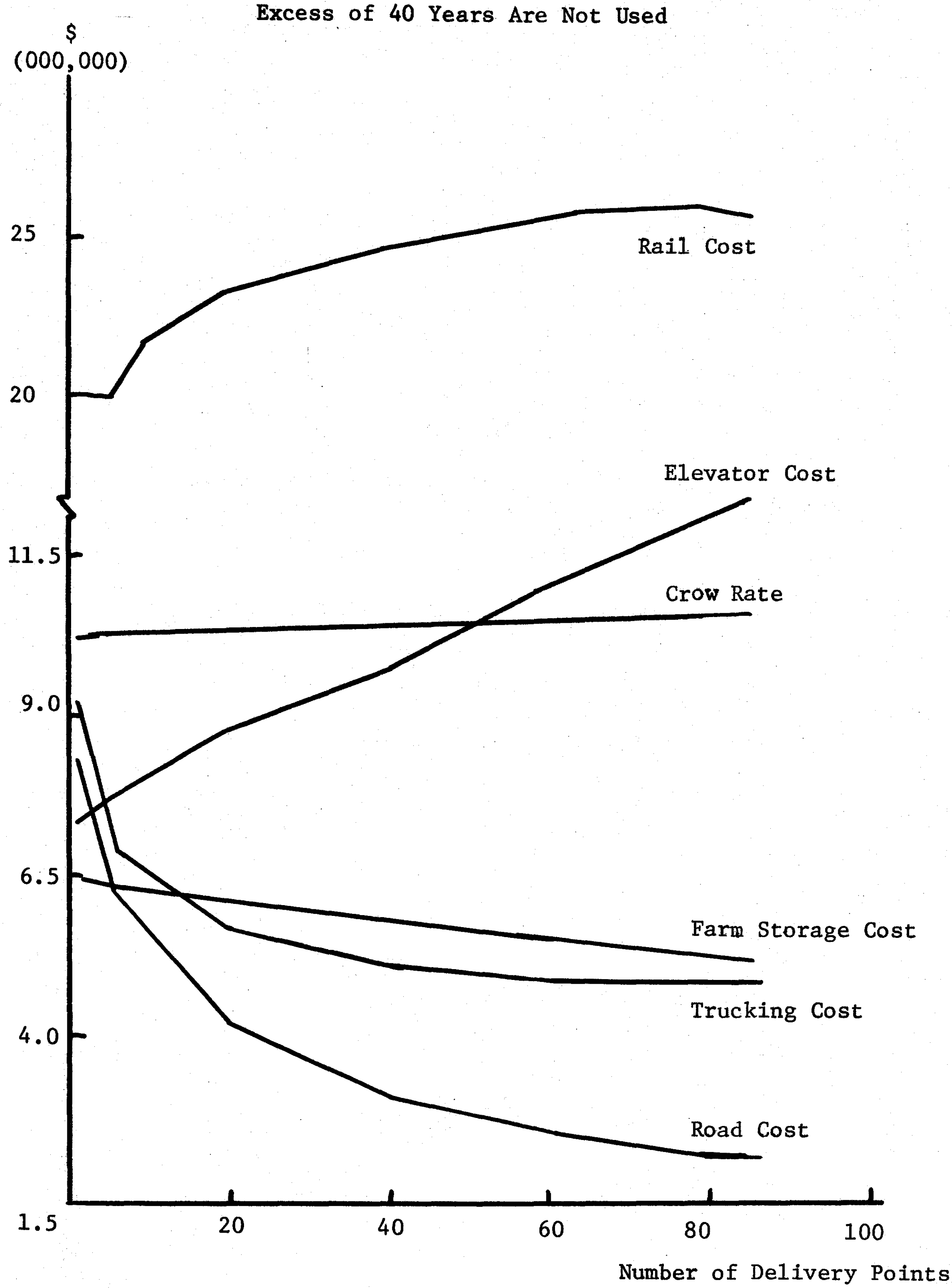
Source: Derived from optimum solution to Case #3 vs. Case #1 (178 pts.)

Grain deliveries to each of the six open points range from 10.7 to 15.0 million bushels annually. Under these conditions the bulk of the elevator capacity was constructed to reduce the handling/capacity ratio to 6:1, the maximum allowed in the case. At all six points the cost of handling grain was at the minimum cost which was 8.021¢ per bushel handled[4/].

4/ Inland terminals and high-throughput elevators are not specifically considered but the cost of handling in these facilities would be similar. (See footnote 7/ Appendix, G.)

Figure 5.8

Component Costs (Case #3) Where Elevators In Excess of 40 Years Are Not Used



Source: Derived from optimal solution to Case #3.

5.5 Case #4 (Replacement of Old Elevators)

All elevators in excess of 40 years were closed, however, all points were considered as potential delivery points by using new facilities where required. Using the Crow rates, the efficient number of delivery points was 60 which lead to a cost of 42.1¢ per bushel. The alternate estimation using rail cost provided a minimum cost of 58.7¢ per bushel with 21 points (Table 5.5)

Table 5.5

System Cost: Case #4 (Replacement of Old Elevators)
$(000,000)

Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2
2	6.31	9.12	8.38	7.48	10.30	20.00	41.59	51.29
10	6.20	6.40	5.66	7.92	10.42	21.05	36.60	47.23
21	6.13	5.69	4.25	8.26	10.48	22.60	34.81	46.93 1/
40	5.98	5.17	3.18	8.91	10.60	24.96	33.84	48.20
60	5.71	4.89	2.66	9.73	10.72	26.63	33.71 1/	49.62
80	5.50	4.77	2.40	10.68	10.72	26.73	34.02	50.03
100	5.22	4.60	2.21	11.73	10.74	26.80	34.49	50.55
120	5.10	4.51	2.08	12.25	10.73	26.97	34.67	50.91
140	4.98	4.45	1.99	12.77	10.74	27.07	34.93	51.26
160	4.92	4.41	1.94	12.94	10.75	27.10	34.96	51.31
178	4.75	4.39	1.92	13.21	10.74	26.97	35.01	51.24

1/ Minimum cost for Crow rate and rail cost options for Case #4

Source: Calculated from optimum solution to Case #4.

The increased cost over the minima in (5.2) are 1.5¢ and 1.6¢ per bushel. These figures are lower than the added cost in Case # 3 where points were closed when elevators were older than 40 years. The number of points providing least cost increased for both options when compared to Case # 3 and the shift in cost burden among components was not as pronounced.

The cost per bushel for the area of replacing elevators in excess of 40 years to retain all 178 points would be 43.8¢ or 64.1¢ per bushel depending on the rail cost option (Figure 5.9, p. 76). This means an increase of 1.7¢ or 5.4¢ per bushel for grain collection in the area if 178 points are to be retained rather than the optimum number found for this case.

5.6 Case #5 (Excess Capacity is Assumed for Elevators)

The country elevator sector of the grain collection system has a history of excess capacity in relation to its potential technical capacity. In this case it is assumed that the characteristic will continue. Elevators in excess of 40 years are closed, and where needed are replaced to maintain a maximum 3:1 handling to capacity ratio (6:1 is standard in all other cases). All 178 points are considered as potential locations for grain delivery. Under these circumstances the costs are minimized at 60.4¢ for 21 points using the railway cost option (Table 5.6, p.75). Where the Crow rate is employed the minimum cost is 45.7¢ per bushel found with 50 points. To maintain the 1974 delivery pattern to 178 points the costs would rise to 67.6¢ and 47.3¢ or an increase of 7.2¢ and 5.7¢ per bushel respectively. The costs for this case, given the assumption of inefficient use of elevators is greater than under any other alternative considered. The component costs and total costs shown in Figures 5.10, p. 77 and 5.11, p. 78.

Table 5.6

System Cost: Case #5 (Inefficient Use of Elevators)
$(000,000)

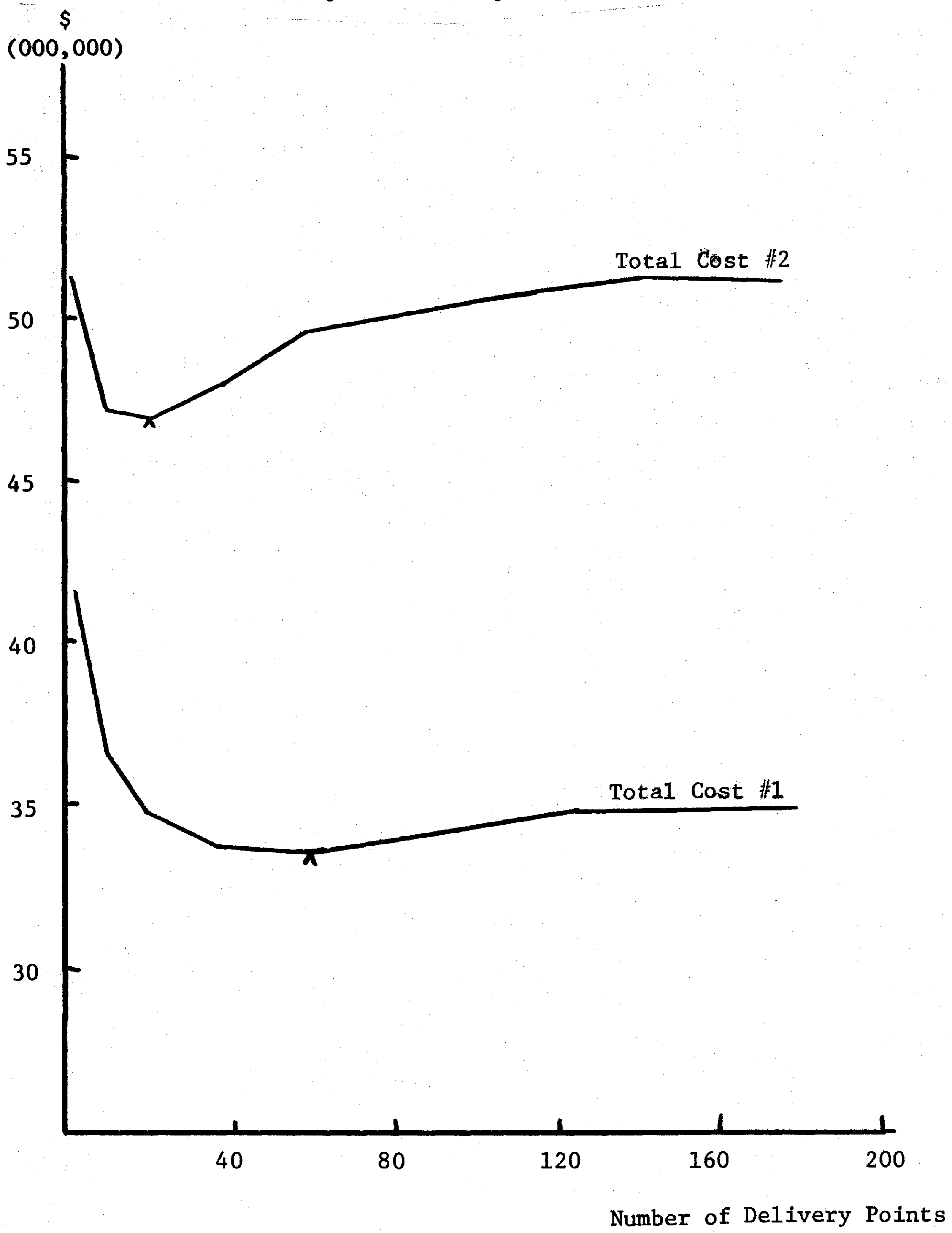
Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2
2	4.99	9.12	8.38	10.75	10.30	20.00	43.54	53.24
10	4.89	6.40	5.66	11.09	10.42	21.05	38.46	49.09
21	4.82	5.69	4.25	11.35	10.48	22.22	36.59	48.29 1/
30	4.72	5.39	3.61	11.77	10.53	23.85	36.02	49.07
40	4.70	5.17	3.18	12.20	10.60	24.96	35.85	50.21
50	4.63	5.02	2.89	12.54	10.66	26.18	35.74 1/	51.26
60	4.51	4.89	2.66	13.27	10.72	26.63	36.05	51.96
80	4.35	4.72	2.40	14.44	10.72	26.73	36.63	52.64
100	4.17	4.60	2.21	15.47	10.74	26.80	37.19	53.25
120	4.10	4.51	2.08	15.10	10.73	26.97	37.52	53.76
140	4.00	4.45	1.99	16.60	10.74	27.08	37.79	54.12
160	3.98	4.41	1.94	16.80	10.75	27.10	37.89	54.23
178	3.85	4.39	1.92	16.95	10.74	26.97	37.86	54.08

1/ Minimum cost for Case #5

Source: Calculated from optimum solution to Case #5

Figure 5.9

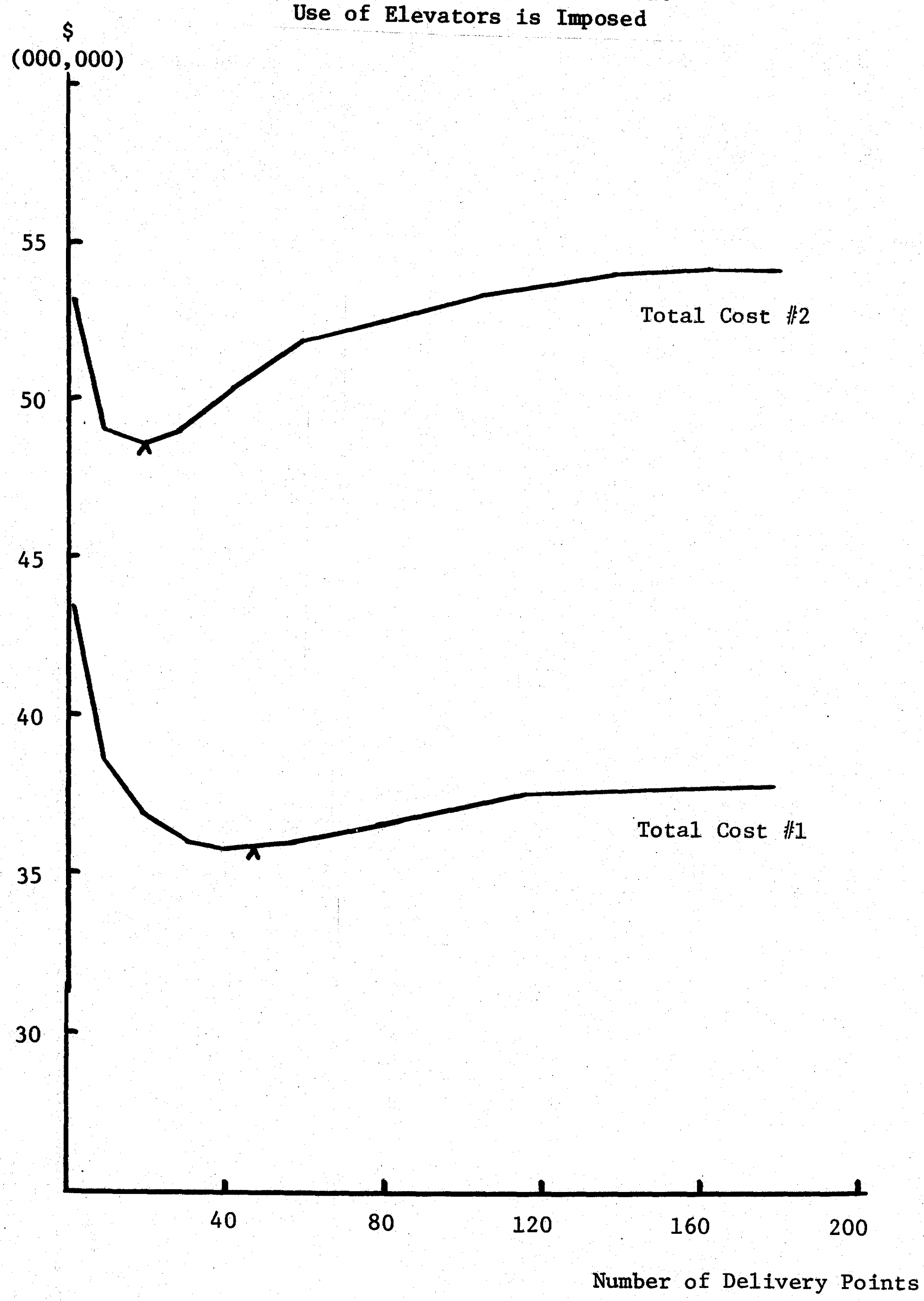
Case #4: Total Costs Where Old Elevators
Are Replaced as Required



Source: Derived from optimum solution to Case #4.

Figure 5.10

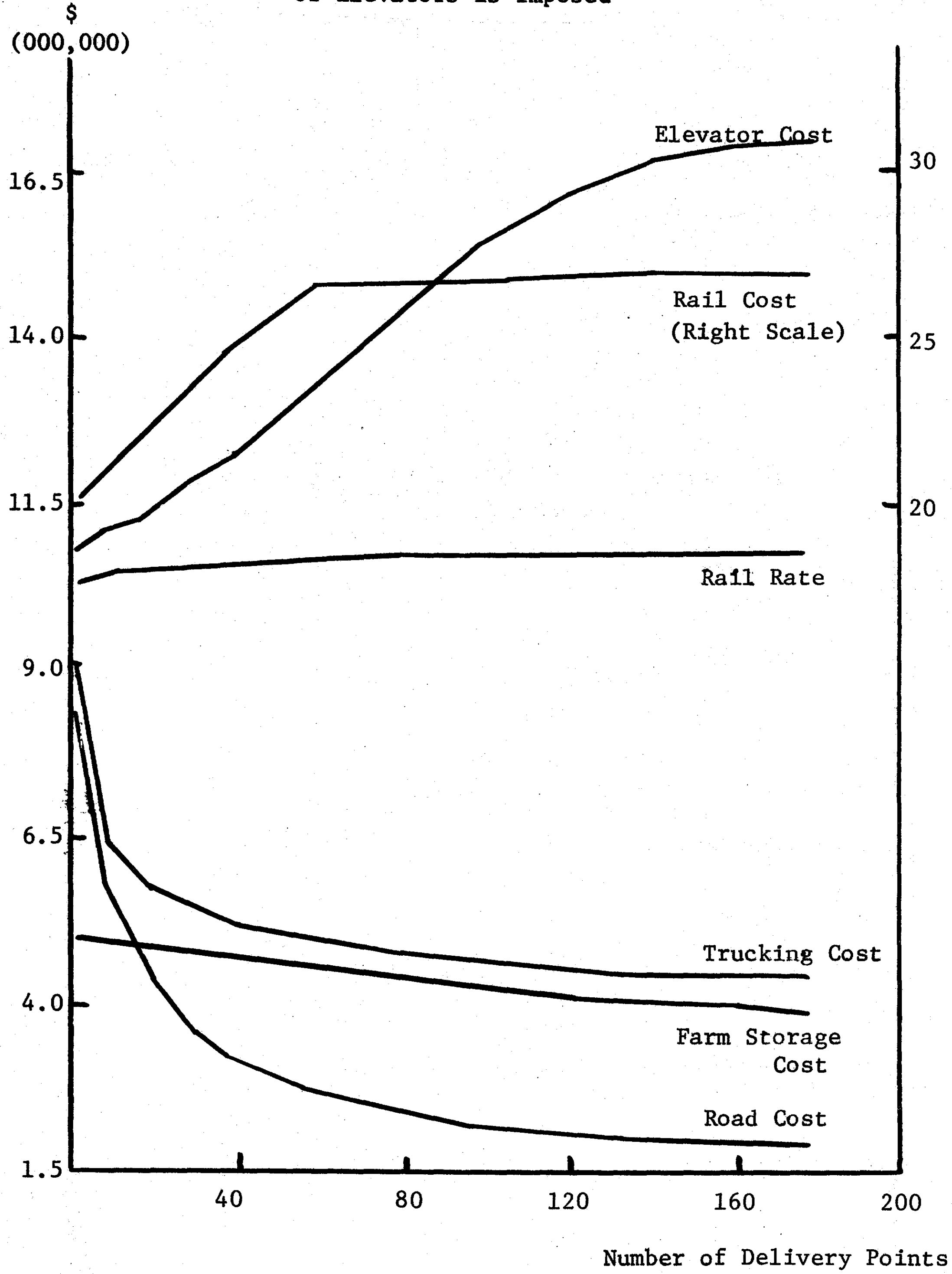
Case #5: Total Costs Where Inefficient Use of Elevators is Imposed



Source: Derived from optimum solution to Case #5.

Figure 5.11

Case #5, Component Costs Where Inefficient Use of Elevators is Imposed



Source: Derived from optimum solution to Case #5.

5.7 Case #6 (New Elevators Assumed to Handle Grain in the Study Area)

In a number of previous studies the savings in grain collection were based on technical efficiency without regard for the duplication normally found in the delivery system. In this estimate all grain delivery points are allowed into the solution but new facilities must be used at each. In other words, if there were no elevators what would a technically efficient system provide in the way of costs and number of delivery points. Again, carrying the parallel railway costing options the minimum costs were achieved at 21 and 107 points (Table 5.7).

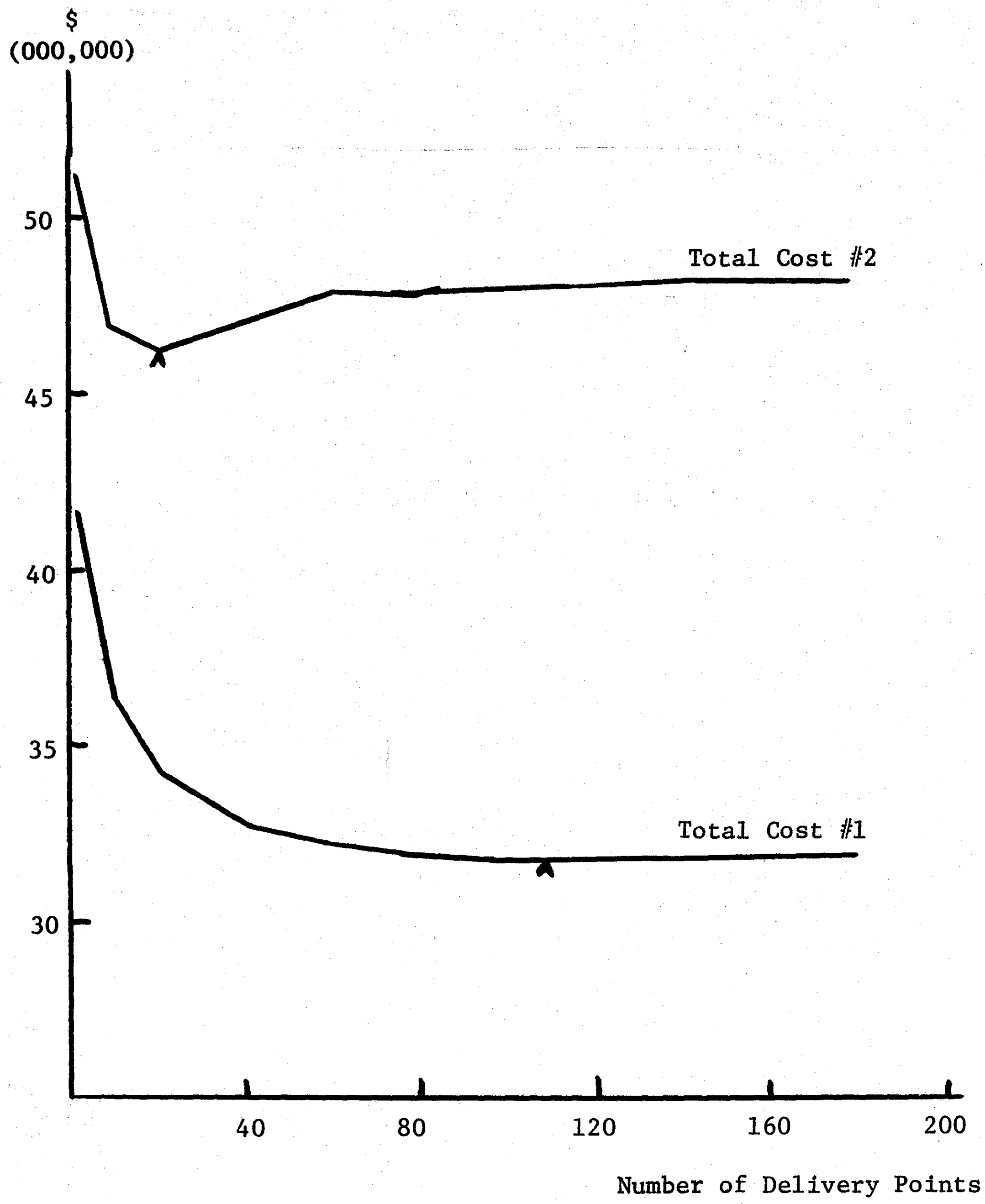
The costs on a bushel basis were 57.9¢ and 39.7¢ respectively. These costs are almost identical to those obtained when existing facilities were used (Section 5.2). Under the conditions of this case the cost would rise to 60.3¢ and 39.9¢ per bushel if all 178 points were to remain open (Figure 5.12, p. 80), having new, efficiently used facilities. This represents an increase in cost of 4.3% and 0.5% for for the two options in this case and a decrease of 2.3% and 3.6% from the cost of maintaining 178 delivery points based on 1974 conditions (Section 5.2)

5.8 Case #7 (One Existing Elevator/Point)

In this case only one elevator was allowed to operate at each point. In all cases it was the newest or largest where two were approximately the same age. All 178 delivery points were allowed into the solution. With the Crow rate option 160 points provided least cost at 30.62 million dollars (Table 5.8, p. 82).

Figure 5.12

Case #6: Total Costs When New Elevators Are Assumed to Handle Grain in the Area



Source: Derived from optimum solution to Case #6.

Table 5.7

System Cost: Case #6 (New Elevators)
$(000,000)

Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2
2	6.33 [2/]	9.12	8.38	7.40	10.30	20.00	41.53	51.23
10	"	6.52	5.66	7.40	10.42	21.05	36.33	46.96
21	"	5.69	4.25	7.40	10.48	22.60	34.15	46.27 [1/]
40	"	5.17	3.18	7.42	10.60	24.96	32.70	47.06
60	"	4.89	2.66	7.50	10.72	26.63	32.10	48.01
80	"	4.72	2.40	7.71	10.72	26.73	31.88	47.89
100	"	4.60	2.21	7.91	10.74	26.80	31.79 [1/]	47.85
107	"	4.57	2.18	8.00	10.73	26.85	31.79	47.93
120	"	4.51	2.08	8.19	10.73	26.97	31.84	48.08
140	"	4.45	1.99	8.40	10.74	27.07	31.91	48.24
160	"	4.41	1.94	8.49	10.75	27.10	31.92	48.27
178	"	4.39	1.92	8.56	10.74	26.97	31.94	48.27

[1/] Minimum cost solution to Case #6

[2/] Farm Storage is constant because efficiency is assumed in elevator operation, i.e. at a constant 6:1 handling/capacity ratio

Source: Calculated from optimum solution to Case #6.

Table 5.8

System Cost: Case #7
(One Existing Elevator/Point)

$(000,000)

Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2
2	6.33	9.12	8.38	7.39	10.30	20.00	41.52	51.22
10	6.33	6.40	5.66	7.33	10.42	21.05	36.14	46.77
20	6.33	5.69	4.25	7.19	10.48	22.22	33.94	45.68 1/
30	6.33	5.39	3.61	7.13	10.53	23.58	32.99	46.04
40	6.33	5.17	3.18	7.19	10.60	24.96	32.47	46.83
60	6.22	4.89	2.66	7.29	10.72	26.63	31.78	47.69
80	6.20	4.72	2.40	7.33	10.72	26.73	31.37	47.38
100	6.17	4.60	2.21	7.32	10.74	26.80	31.04	47.10
120	6.12	4.51	2.08	7.41	10.73	26.97	30.85	47.09
140	6.05	4.45	1.99	7.49	10.74	27.07	30.72	47.05
160	5.98	4.41	1.94	7.63	10.75	27.10	30.62 1/	46.97
178	5.91	4.39	1.92	7.77	10.74	26.97	30.73	46.96

1/ Minimum cost solution to Case #7

Source: Calculated from optimum solution to Case #7.

This total cost translates into a cost of 38.3¢ per bushel which increased to 38.4¢ when all points are open (Figure 5.13, p. 84). When the alternate rail cost method was employed the estimated minimum cost was 45.68 million dollars at 20 points. This is a cost of 57.1¢ per bushel which increased to 58.7¢ when all 178 points are operating.

The change in component costs for this case are presented in Figure 5.14, p. 85. Case #7 resulted in the lowest system cost among the alternatives considered. It also lead to the largest number of delivery points at the efficient level for the Crow Rate option and the least cost of increasing points to the maximum number for the area.

178 points with one existing elevator at each resulted in a greater saving of 2.0¢ (for the Crow rate option) and an added cost of 1.5¢ (for the rail cost option) when compared the efficient numbers (80 and 21) in the benchmark, Case #1 (Section 5.2).

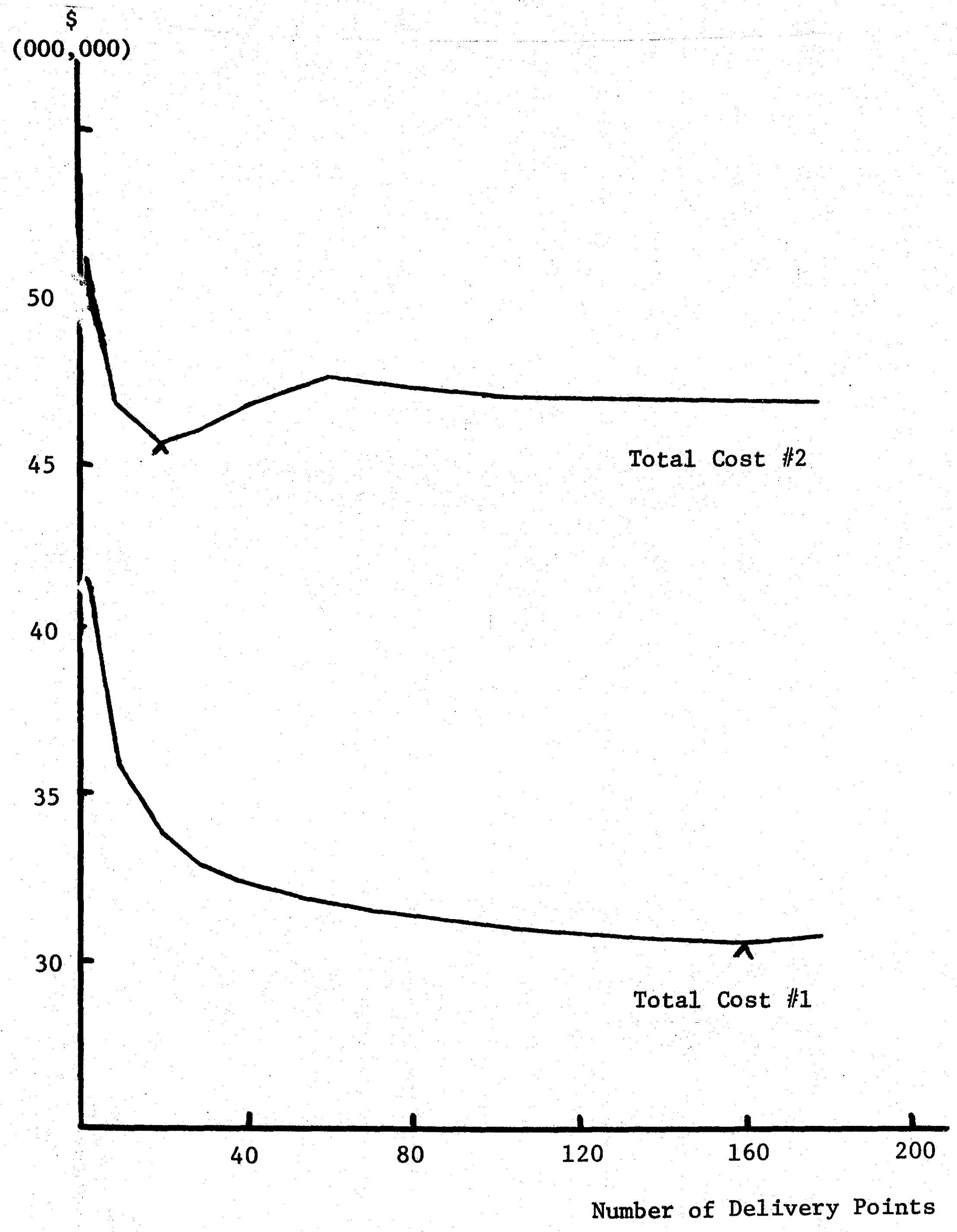
5.9 Case #8 (Two Existing Elevators/Point)

In this case regulation of the country elevator component provides limited choice for producer delivery at each point. No age limit is placed on facilities and no more than two existing facilities are allowed at any point. The assumption is also made that 31 small delivery points in the area which were closed since 1974 are not considered as potential delivery locations.

Of the 147 possible locations, given the assumptions, the minimum cost was achieved at 100 points when the Crow rate was used. 10 points provided minimum system cost when the railway cost was employed (Table 5.9, p. 86). The cost on a bushel basis were 39.1¢ and 58.5¢ a

Figure 5.13

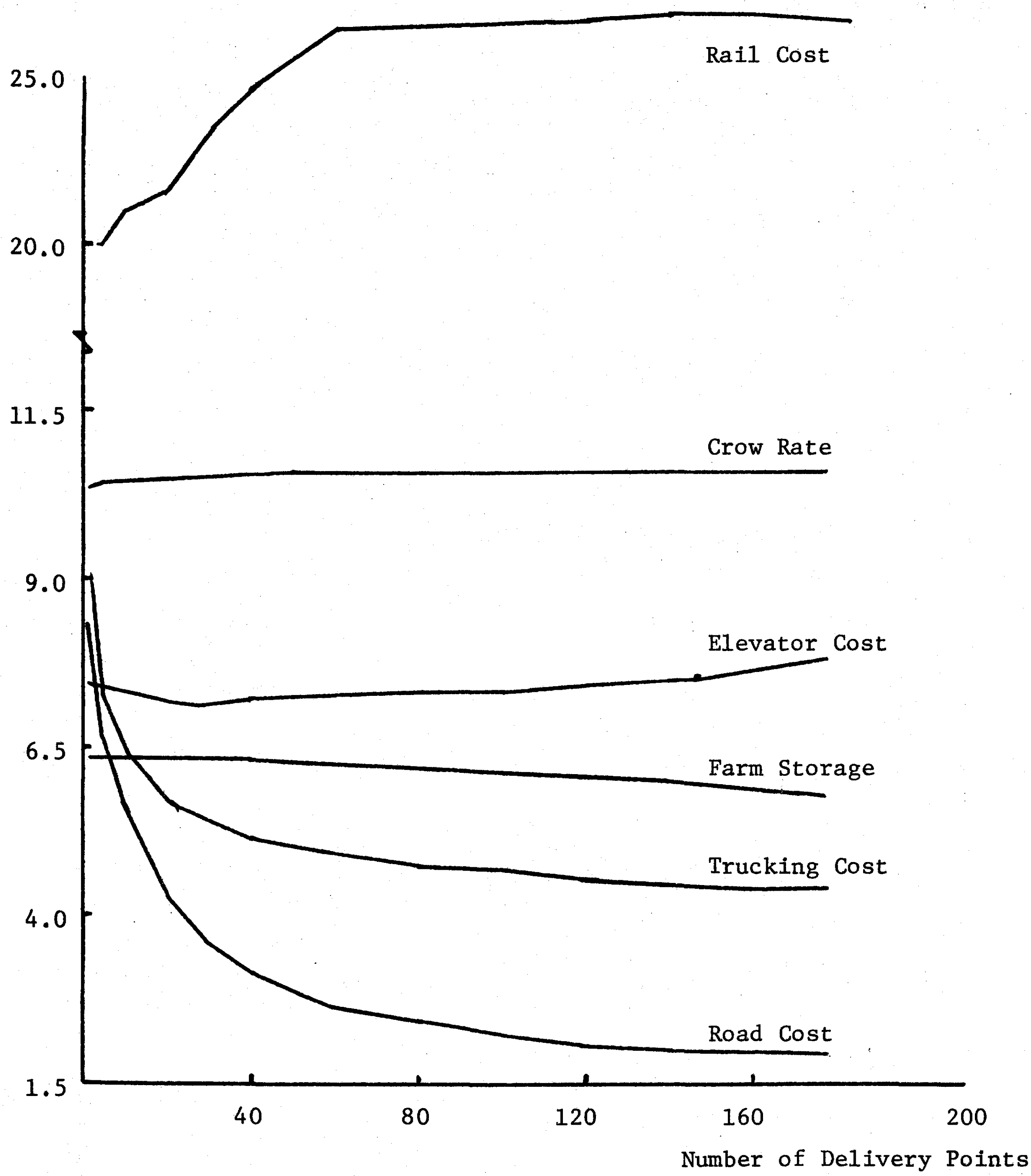
Case #7: Total Costs When One Existing Elevator/Point is Assumed



Source: Derived from optimum solution to Case #7.

Figure 5.14

Case #7, Component Costs When One
Elevator is Assumed at Each Point



Source: Calculated from optimum solution to Case #7.

reduction of 2.4¢ and 3.4¢ in total cost when compared to the 1974 system with 178 points (Table 5.1). The cost of operating all 147 points in this case were 39.7¢ and 59.9¢ per bushel (Figure 5.15, p. 87). Note however that increasing from 10 to 100 delivery points (assuming the rail cost option) the increase in Total Cost is only 0.2¢ per bushel.

Table 5.9

System Cost: Case #8
(Two Elevators/Point)
$(000,000)

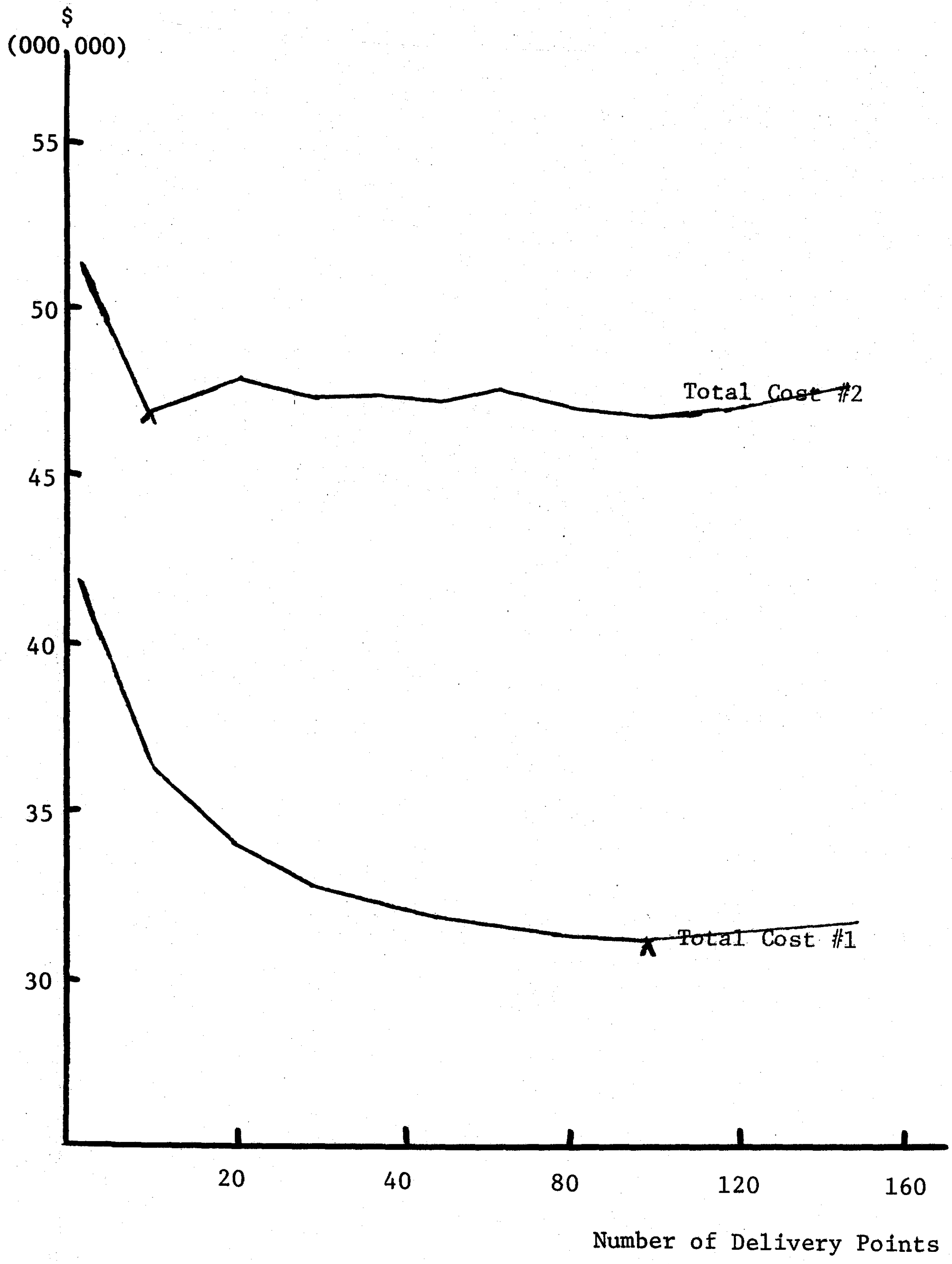
Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2
2	6.33	9.15	8.42	7.39	10.30	20.00	41.59	51.29
10	6.33	6.43	5.81	7.25	10.44	20.99	36.26	46.81 1/
20	6.33	5.73	4.37	7.14	10.48	24.35	34.05	47.92
30	6.32	5.38	3.56	7.10	10.54	24.95	32.90	47.31
40	6.31	5.16	3.16	7.11	10.61	25.70	32.35	47.44
50	6.22	5.00	2.83	7.17	10.65	26.03	31.87	47.25
60	6.16	4.87	2.62	7.32	10.71	26.59	31.68	47.56
80	5.88	4.71	2.36	7.70	10.72	26.39	31.37	47.04
100	5.64	4.59	2.19	8.15	10.73	26.36	31.30 1/	46.93
120	5.42	4.51	2.08	8.69	10.73	26.51	31.43	47.21
140	5.21	4.46	2.01	9.19	10.74	27.01	31.61	47.88
147	5.14	4.55	2.00	9.36	10.74	26.88	31.79	47.93

1/ Minimum total cost for Case #8.

Source Calculated from optimum solution to Case #8.

Figure 5.15

Case #8: Total Cost
(Two Existing Elevators/Point)



Source: Derived from optimum solution to Case #8.

In Case #8 where a mininum level of competition at individual delivery points was assumed the cost was .8¢ per bushel higher for the Crow rate option and 1.8¢ per bushel higher for the rail cost option. Fewer points provided least cost collection when limited competition was introduced.

5.10 Case #9 (Constraints on the Location of Delivery Points and Use of Rail Lines)

In this case 13 branch lines were closed (Figure 5.16, p. 89), 31 small points were closed and 17 points were forced initially. The forced points were the large towns or cities and points with a record of one million bushel or greater handlings (Figure 5.16, p. 89).

The minimum cost number of points ranged from 40 to 60 with a cost of 32.75 to 32.77 million dollars or 40.9¢ per bushel when the Crow rate option was employed (Table 5.10, p. 91). When the railway cost was employed the minimum was 45.32 million or 56.7¢ per bushel at 20 points. These figures compare with 40.5¢ and 57.2¢ found when all points and all lines were available for consideration. The costs increased in this case to 41.5¢ and 58.9¢ when 102 points, the maximum available, were operated (Figure 5.17, p. 90).

5.11 Case #10 (Constrained System with 25% Increased Deliveries)

This case is identical with the previous case except total grain delivered was increased 25% for each delivery point. This represents a figure comparable to the increase in deliveries in the last two - three years over the ten year average.

The efficient number of points based on the Crow rate was 61 whereas when the railway cost was used the efficient number of points

Figure 5.16

Case #9 (Constraints on the Location of Delivery Points and Use of Rail Lines)

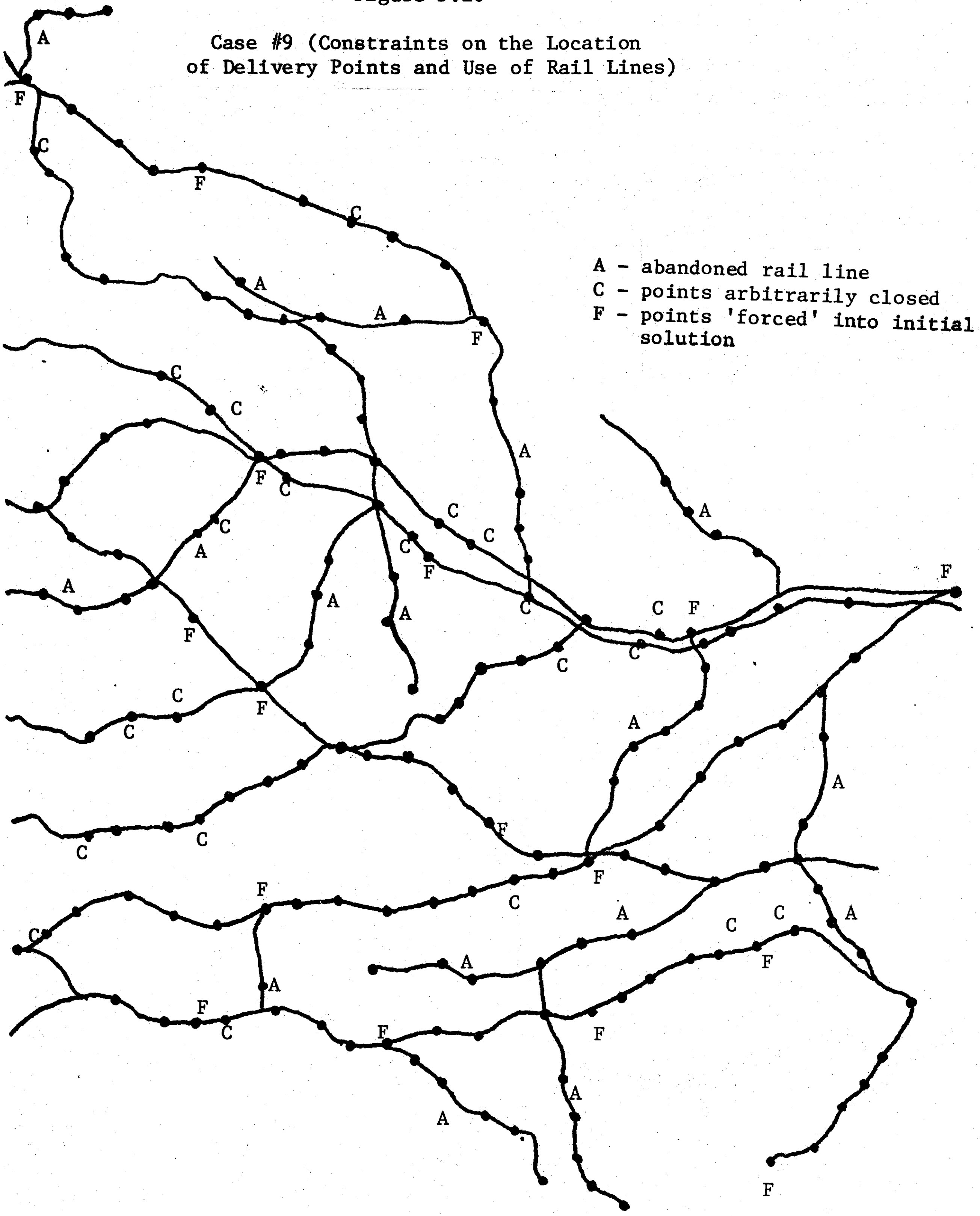
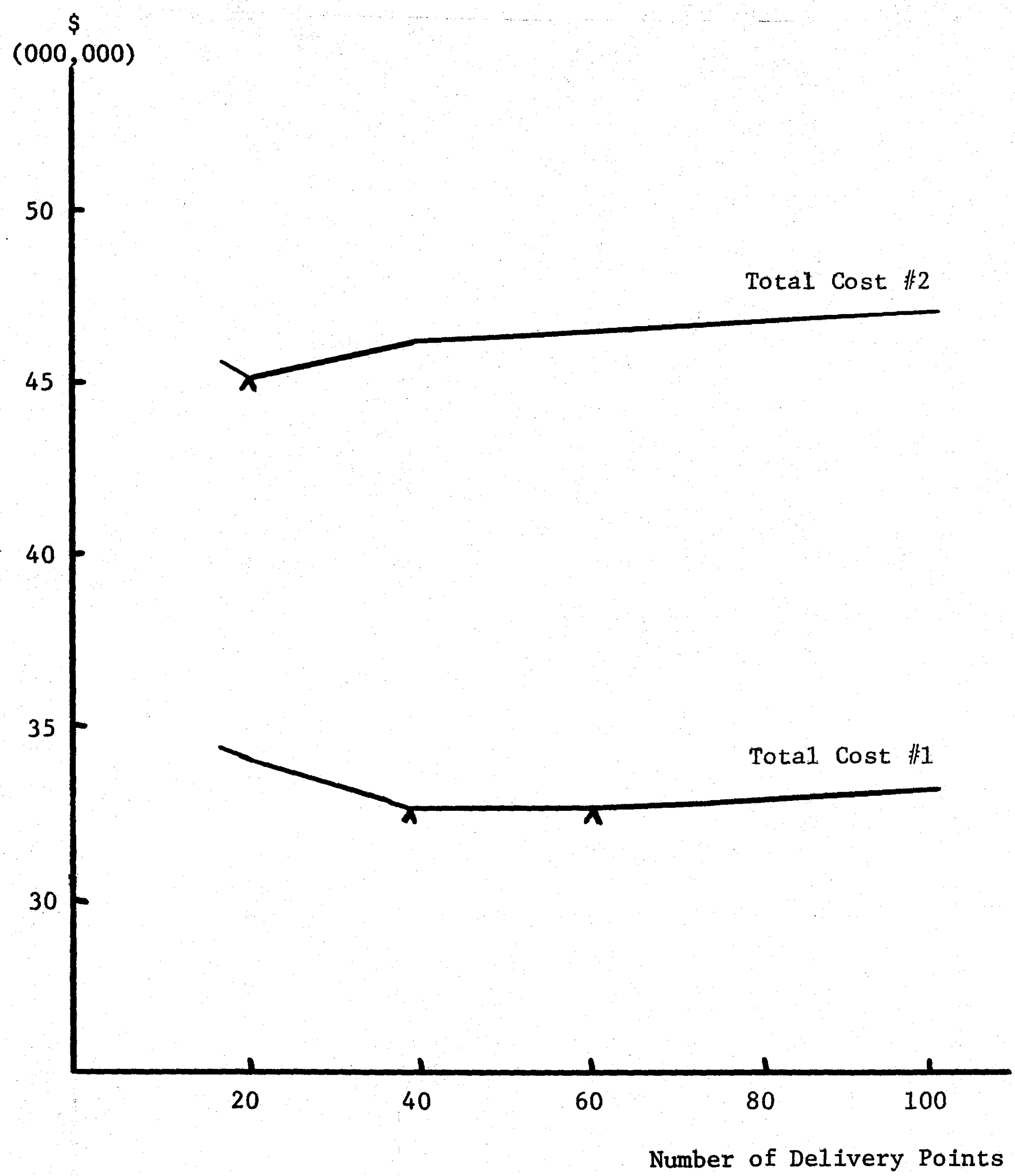


Figure 5.17

Case #9: Total Costs
(Constrained Location for Delivery Points and
Use of Rail Lines)



Source: Derived from optimum solution to Case #9.

Table 5.10

System Cost: Case #9
(Constraints on the Location of
Delivery Points and Use of Rail Lines)
$(000,000)

Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2
18	6.20	6.01	5.11	6.71	10.44	21.49	34.47	45.52
20	6.12	5.87	4.77	6.94	10.47	21.62	34.17	45.32[1/]
40	5.77	5.24	3.41	7.73	10.60	24.29	32.75[1/]	46.44
60	5.39	5.03	3.05	8.64	10.66	24.46	32.77	46.57
80	4.96	4.91	2.76	9.61	10.67	24.38	32.91	46.62
102	4.72	4.85	2.70	10.23	10.68	24.65	33.18	47.15

1/ Minimum cost solution to Case #9

Source: Calculated from optimum solution to Case #9.

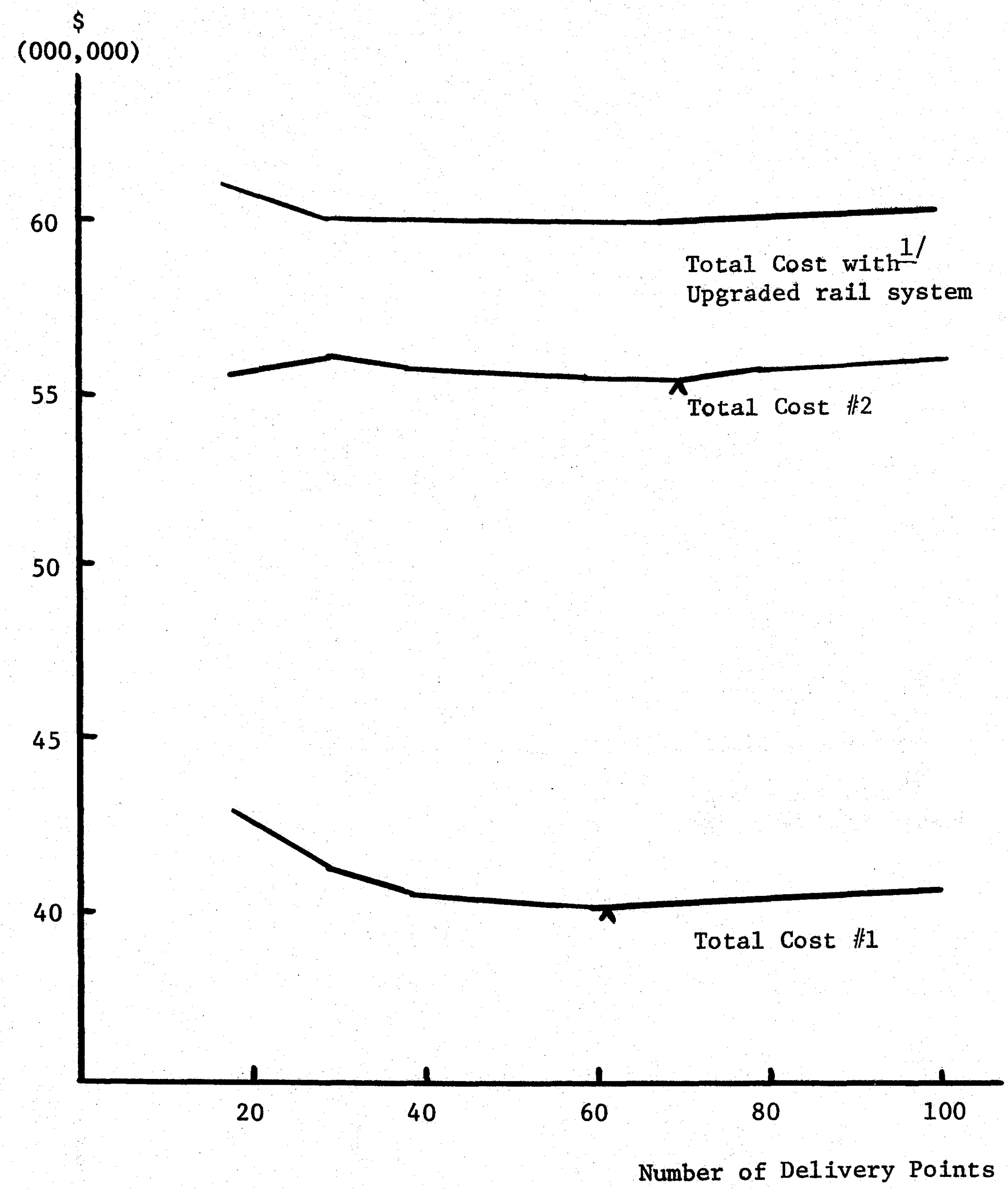
increased to 70.[5/] The respective costs were 40.3¢ and 55.5¢ (Table 5.11, p. 94).

The Cost per bushel with 25 percent greater deliveries decreased 0.6¢ and 1.2¢ compared to Case #9 where all other conditions were the same. The number of delivery points increased from 1 to 21 for one option and by 50 for the other. With an increase in costs per bushel of 0.3¢ and 0.8¢ the number of points could be increased to the maximum 102 available for this case (Figure 5.18, p. 92).

5/ Note the optimal number of delivery points is greater for the rail cost option than for the Crow Rate option which may be accounted for by a virtually constant total cost over a wide range of delivery points.

Figure 5.18

Case #10: Total Costs (Constrained System with 25% Increase in Deliveries)

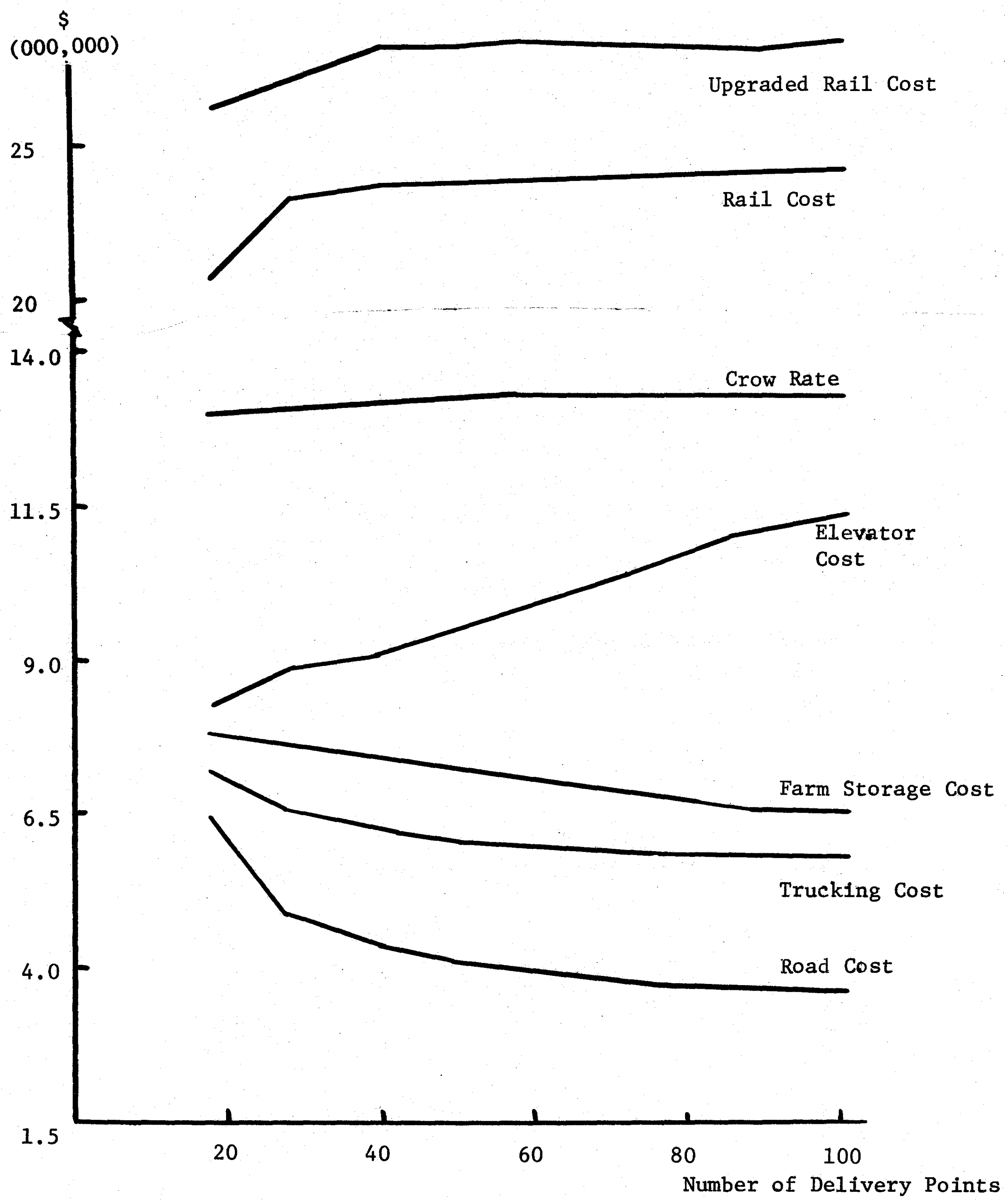


1/ See section 5.12.

Source: Derived from optimum solution to Case #10.

Figure 5.19

Case #10, Component Costs
(Constrained System with 25% Increased Deliveries)



Source: Derived from optimum solution to Case #10.

Table 5.11

System Cost: Case #10
(Constrained System with 25% Increase in Deliveries)
$(000,000)

Points	F.S.	Tr.	Rd.	El.	Rail #1	Rail #2	Tot #1	Tot #2
18	7.76	7.21	6.48	8.35	13.06	25.75	42.86	55.55
30	7.59	6.52	4.88	8.84	13.16	28.18	40.89	56.01
40	7.46	6.25	4.37	9.09	13.25	28.59	40.42	55.76
46	7.31	6.15	4.19	9.47	13.28	28.40	40.40	55.52
51	7.25	6.08	4.06	9.63	13.30	28.59	40.32	55.61
61	7.10	5.98	3.90	9.96	13.33	28.62	40.27[1/]	55.56
70	6.90	5.91	3.80	10.38	13.34	28.50	40.33	55.49[1/]
80	6.73	5.85	3.71	10.85	13.34	28.70	40.48	55.84
90	6.59	5.80	3.64	11.32	13.34	28.69	40.58	55.93
100	6.51	5.77	3.60	11.38	13.34	28.83	40.60	56.09
102	6.50	5.77	3.60	11.42	13.34	28.98	40.63	56.27

[1/] Minimum cost solution to Case #10

Source: Calculated from optimum solution to Case #10.

The component costs in this case (Figure 5.19, p. 93) as in Case #9 are more stable over the range of points considered than was true with the first eight cases analyzed.

5.12 A Third Rail Cost Option

The third rail cost option was carried in all cases which represented an hypothetical improvement of rail lines (Section 4.5.5).

The result in all cases was a total cost greater than either of the two and with a minimum found at fewer points. Figures 5.1 and 5.18 demonstrate the nature of this cost for Case #1 and Case #10 in relation to the other options. A small deviation in the number of points from the minimum cost number results in a large change in total costs as shown in Figure 5.1, a typical situation. Figure 5.18 demonstrates an exception to the general condition. The general conditions holds for all cases excepting Case #9 and Case #10. The component cost changes are generally more pronounced due to the minimum falling at very few points (Figure 5.2, p. 62). The percentange change in component costs for Case #1 under the three options are shown in Table 5.12.

Table 5.12

Change in Component Cost Burden (Case #1)

Component	Change to 80 pts.	21 pts.	13 pts.
Farm Storage	+36.3%	+62.9%	+59.2%
Trucking	+ 7.5%	+29.6%	+38.0%
Roads	+25.0%	+121.4%	+259.9%
Elevators	-24.4%	-41.4%	-69.8%
Railways	- 0.2%	-17.6%	-26.5%
Total	- 2.4%	- 7.4%	- 8.9%

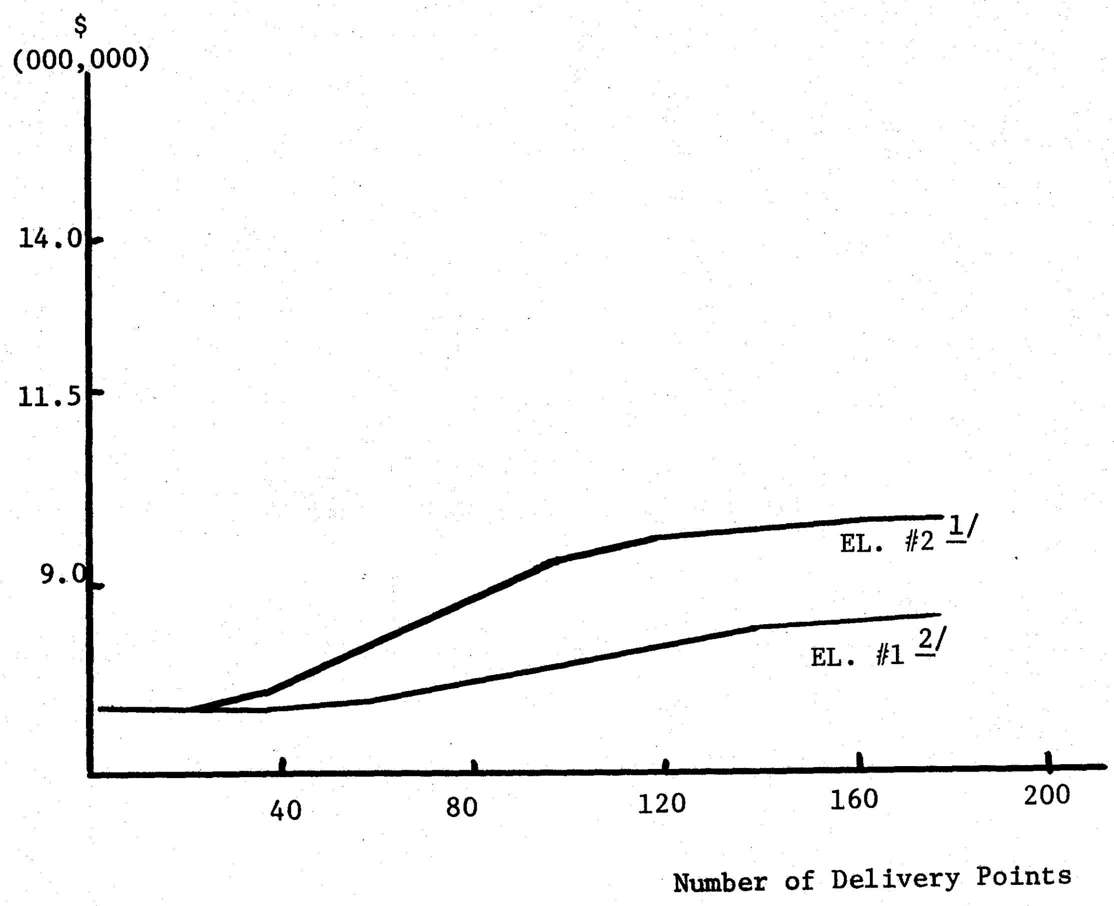
Source: Derived from optimum solution to Case #1

5.13 Elevator Cost Options

The cost of elevators when added capacity was required was calculated under two options. Either as one facility or two of equal size. This was an attempt to determine the change in system costs where 'opposition' existed at individual points. The effect was negligible in most cases as facilities were generally only required when a few points were operational. In these circumstances the elevator cost encountered was the minimum considered feasible for operating new facilities. The one exception was Case #6 where all elevators were costed as if new in 1974. There was no difference between the two options until 30 points were reached up to which the enforced elevator cost minimum was in effect. Therefore, no change in the 21 point solution was encountered for the railway cost option. Where the Crow rate was applied the optimum number of points was found at 60 rather than 107. The cost was an additional 1.65 million dollars for the elevator component (Figure 5.20 p. 97). The cost at 60 points was 40.9¢ per bushel compared to 39.7¢ with only one elevator. The cost rose to 41.6¢ when all 178 points were operated compared to 39.9¢ without 'opposition' at individual delivery points.

Figure 5.20

Case #6, Change in Elevator Costs with
Change in Number of Delivery Points



1/ EL #2 = cost of operating elevators when two of equal size were assumed to exist at individual delivery points

2/ EL #1 = cost of operating elevator when one elevator was assumed at each point.

Source: Derived from optimal solution to Case #6

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Summary

The objective of this study was to confront centralization of the grain handling and transportation system to determine the optimal number of delivery points required in Saskatchewan under various assumptions. A cost approach was used and the study emphasized the relationship between grain producers and the collection industry. Five components were included in the system: 1) trucking, 2) elevators, 3) railroads, 4) farm storage and 5) roads. An area study research design was adopted to cope with data and technical limitations.

Ten cases were tested using a transportation location model modified after the Stollsteimer approach. A suboptimal search procedure was employed to obtain a solution for each case. The study does not generate the absolute minimum cost of grain collection for the system. The solution procedure was designed to provide a high degree of flexibility to incorporate a range of technical and policy conditions and corresponding least cost solutions.

Two rail cost options are presented for each case; 1) is the Crow rate and 2) a freight cost based on information presented to the CTC by the railways. The individual cases vary according to assumptions concerning; 1) the number of delivery points, 2) use of existing elevators, 3) use of rail lines, 4) level of grain deliveries, and 5) handling of elevators. The results of each case are presented graphically in Figure 6.1.

Figure 6.1 summarizes the results of Chapter V. The results of each case are presented for the optimum (i.e.: least cost) number of points and also for the maximum number of points. The figures give the cost of each component, and the total cost in cents/bushel. For example, the first column of Case #1 gives the results for the minimum cost number of points (21) assuming that the rail cost option was used in the total. The second column gives the results of the least cost number of points (80) when the Crow rate was used. The third column gives the results for maximum number of points (178) for both rail options. The total cost figures for each option are presented at the top of each column except for the Crow rate at the maximum number of points which is presented above the broken line. In Case #1 the saving obtained by reducing from 178 to 80 delivery points is: 41.5 - 40.4 = 1.1¢/bushel when the Crow rate is used. Similarly, when the rail cost is used the saving is 61.8¢ - 57.2¢ = 4.6¢/bushel when the number of delivery points is reduced to 21.

The individual cells of each column show the composition of total cost in terms of the five components. Comparing one column to the others in each case demonstrates the change in burden of cost. For example, taking the rail cost option for Case #1 farm storage increase from 4.9¢/bushel at 178 points to 7.9¢/bushel at 21 points (Column 3 vs. Column 1). Similarly, for the rail component the cost at 178 points in 33.7¢/bushel which reduces to 27.8¢/bushel at 21 points.

Comparisons of one case to another demonstrates the influence of the underlying conditions for each case. For example, Case #1 represents 1974 conditions in the study area while Case #2 represents the system with 31 small points closed. Using the rail cost option the

Figure 6.1 Summary of Results

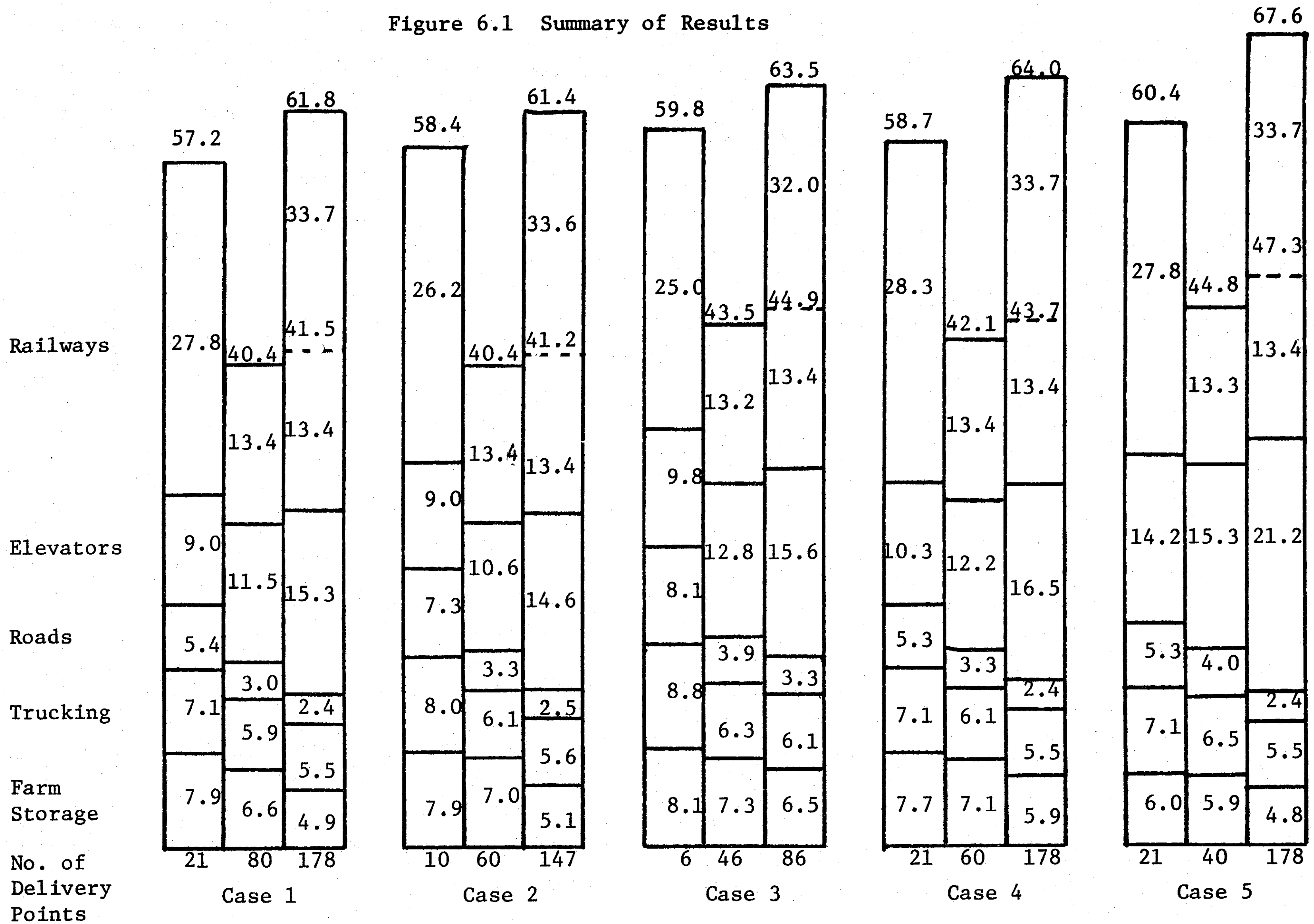
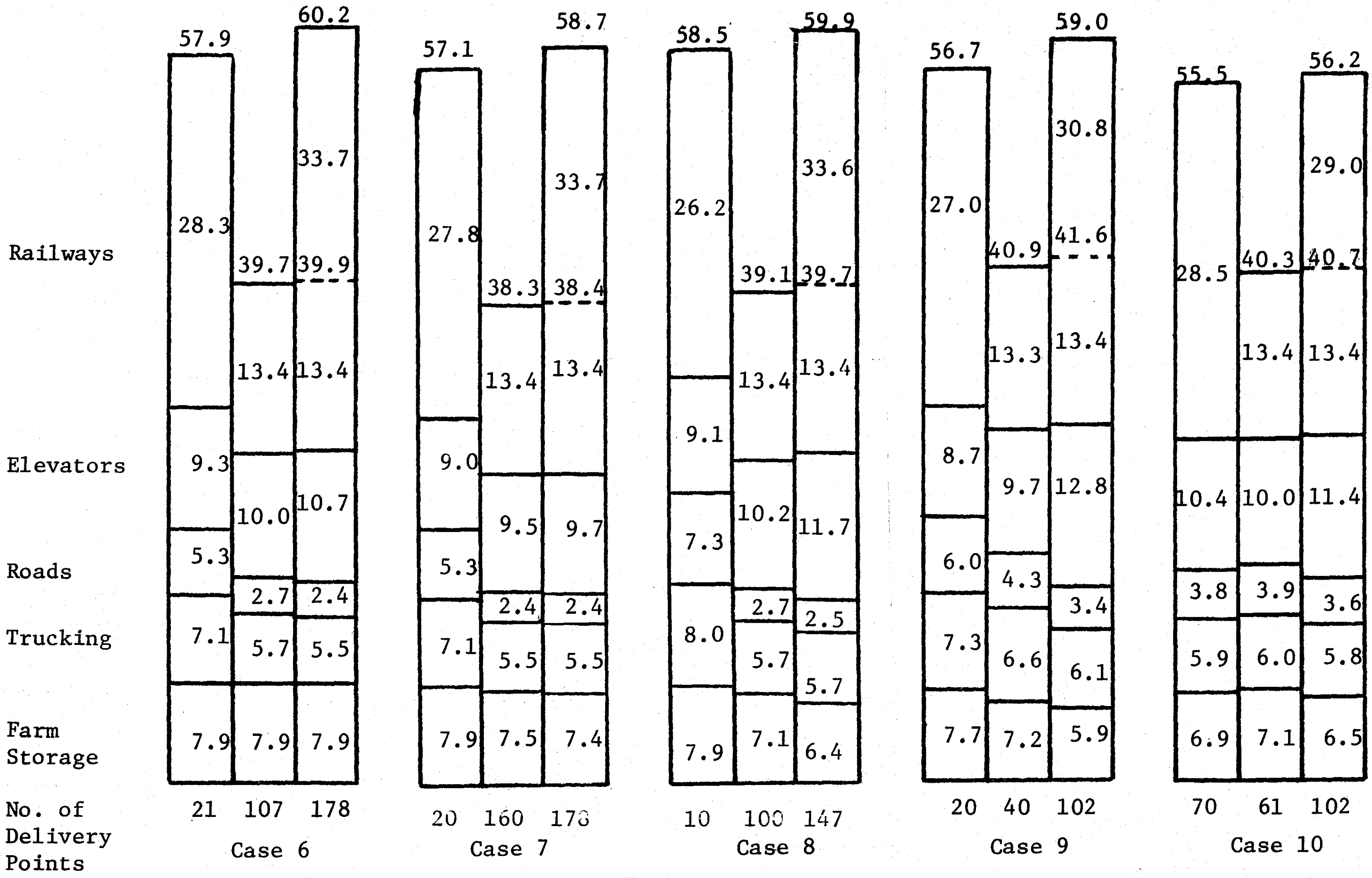


Figure 6.1 Continued



Source: Derived from optimal solutions to cases analysed.

cost number of points decreased from 21 to 10 and the cost per bushel rose 1.2¢ (Case #1, Column 1 vs. Case #2, Column 1).

In general the study shows that the cost of grain collection in 1974 in the study area could be reduced. First, as shown in Case #1 (figure 6.1) reduction of the number of delivery points (given existing facilities) would reduce cost, 4.6¢/bushel for the rail cost option and 1.1¢ for the Crow rate option. The small saving observed for the Crow rate option is due to the constant nature of the rate, whereas 5.9¢/bushel was saved in the rail component when the rail cost option was employed. The results of centralization is a shift in the burden of cost from rail and elevator components to farm storage, trucking and road components.

Closure of 31 delivery points in the study area lead to a reduction in the cost of grain collection of 0.2-0.3¢/bushel (Case #2, figure 6.1). The 31 points closed are those which were in fact closed since 1974 in the study area. To obtain the efficiency of the consolidated 1974 system the number of points required was reduced from 21 to 10 points and from 80 to 60 points (see the comparison of the optimal solutions to Case #1 and Case #2, figure 6.1). This lead to a greater shift in cost among components.

There are many old elevators in the study area, closure of all those over 40 years resulted in closure of 92 delivery points. A collection system operating with the remaining 86 points cost 1.7¢/bushel more than the 1974 system (Case #1, 178 points vs. Case #2, 86 points. The cost was greater because 1) new facilities were required at the remaining delivery points to maintain a 6:1 handling to capacity ratio as the maximum and 2) the spatial dispersion of delivery points was not obtained when age of elevators resulted in closure of delivery points. Consolidation to 6 and 46 points resulted in lower cost but not to the level which could be obtained when all 178 delivery points were available to choose from i.e.: Case #1 @ 21 and 80 points.

When elevators greater than 40 years were closed but all 178 points were available for delivery, through building new elevators where necessary, the efficient number of delivery points increased and the cost per bushel declined (figure 6.1, Case #3 vs. Case #4). In this case where spatial dispersion was allowed new facilities were built at points with no other facilities thus avoiding the duplication found in the previous case and simultaneously reducing the assembly cost (trucking and roads).

Over capacity in the elevator component as expressed in the handling to capacity ratio is a characteristics of the grain collection system. A 3:1 ratio as a maximum[1/] for individual elevators lead to the highest cost case tested (Case #5). Centralization from 178 to 21 and 50 points was required to minimize costs under the 3:1 conditions. For the rail <u>cost</u> option the saving was 1.4¢ (Case #5, Column 1 vs. Case #1, Column 3) and for the Crow <u>rate</u> the additional cost was 3.3¢ (Case #5, Column 2 vs. Case #1, Column 3). Inefficient use of elevators in this case lead to the greatest cost of a decentralized collection system.

1/ A 6:1 handling to capacity ratio was the standard maximum in all other cases tested.

If no elevators existed, what would the cost of grain collection be with a new set of efficient elevators (i.e.: operated at 6:1 handling to capacity) located at present delivery points? The cost of handling grain under these conditions was lower than the cost with the 1974 facilities (Case #6, Column 3 vs. Case #1, Column 3). A new, efficient elevator system would result in an 0.7¢/bu. increase in cost with the optimum number of points (21) given the rail cost option. A saving of 0.7¢/bushel is the result when using the Crow rate option and 107 points an increase of 27, are efficient.

In all ten cases tested the least cost of handling grain assuming the Crow rate was obtained when one existing elevator was operated at each open point. One hundred and sixty points lead to the least cost (Case #7) and 0.1¢ was saved by reducing to those points from the maximum 178 available. By comparison, two existing elevators operating at each point lead to an increase in cost (approximately 1¢/bushel) and a decrease in the number of points that provide efficient grain collection (figure 6.1, Case #7 vs. Case #8). When the rail rate was incorporated in the total cost 20 points provided efficient service with one elevator at each point with a cost of 57.1¢/bushel. Increasing to 2 elevators/point decreased the optimal number of points to 10 and increased the cost to 58.5¢/bushel.

A combination of conditions which included 1) an arbitrary selection of large towns and delivery points, 2) closure of small delivery points and 3) rail line abondonment resulted in a minimum cost system at 20 and 40 points (Case #9), 20 points for the rail cost option, 40 points for the Crow Rate option. The saving for the rail cost option was 5.1¢ when compared to 1974 conditions (Case #9, 20 points vs. Case #1, 178 points). The saving for the Crow rate option was 0.6¢/bushel. When the same conditions were applied to the system with a 25 percent increase in handlings the cost per bushel declined (Case #9 vs. Case #10), the efficient number of points increased from 20 to 70 and from 40 to 61, and the saving from operating the maximum 102 points was 0.3¢ /bushel. The conditions of Case #10 (for the rail cost option) resulted in the most efficient system (55.5¢/bu.) and the maximum number of delivery points (70).

A third cost option which provided for an hypothetical improvement of rail lines resulted in higher costs and fewer delivery points under all conditions. Rail cost, generally the largest cost component, is reduced when the number of delivery points is reduced. The dominance of rail cost was even more pronounced when improvements in rail lines were hypothesized therefore fewer delivery points provided efficient service but at higher cost.

An alternate elevator cost option that provided for competition through use of two equal sized new facilities where required had a minimal impact on the system except where new elevators were assumed at all points (Case #6). The cost increased 1.2 and 1.7¢/bushel and the number of delivery points required to provide efficient service declined for the Crow rate option. The efficient number of delivery points did not decline for the rail cost option because under both conditions (1 or 2 elevators) the cost of handling grain was at the enforced minimum for new facilities.

The initial conditions and restrictions on the grain delivery system had a major impact on the nature and level of the total cost of collection for the study area. This demonstrates the importance of a number of policy decisions for 1) the number of delivery points that provide least cost service, 2) the level of the cost and 3) the saving due to centralization. A comparison of the 10 cases for the rail cost option is found in figure 6.2 and in figure 6.3 for the Crow rate.

6.2 Conclusions

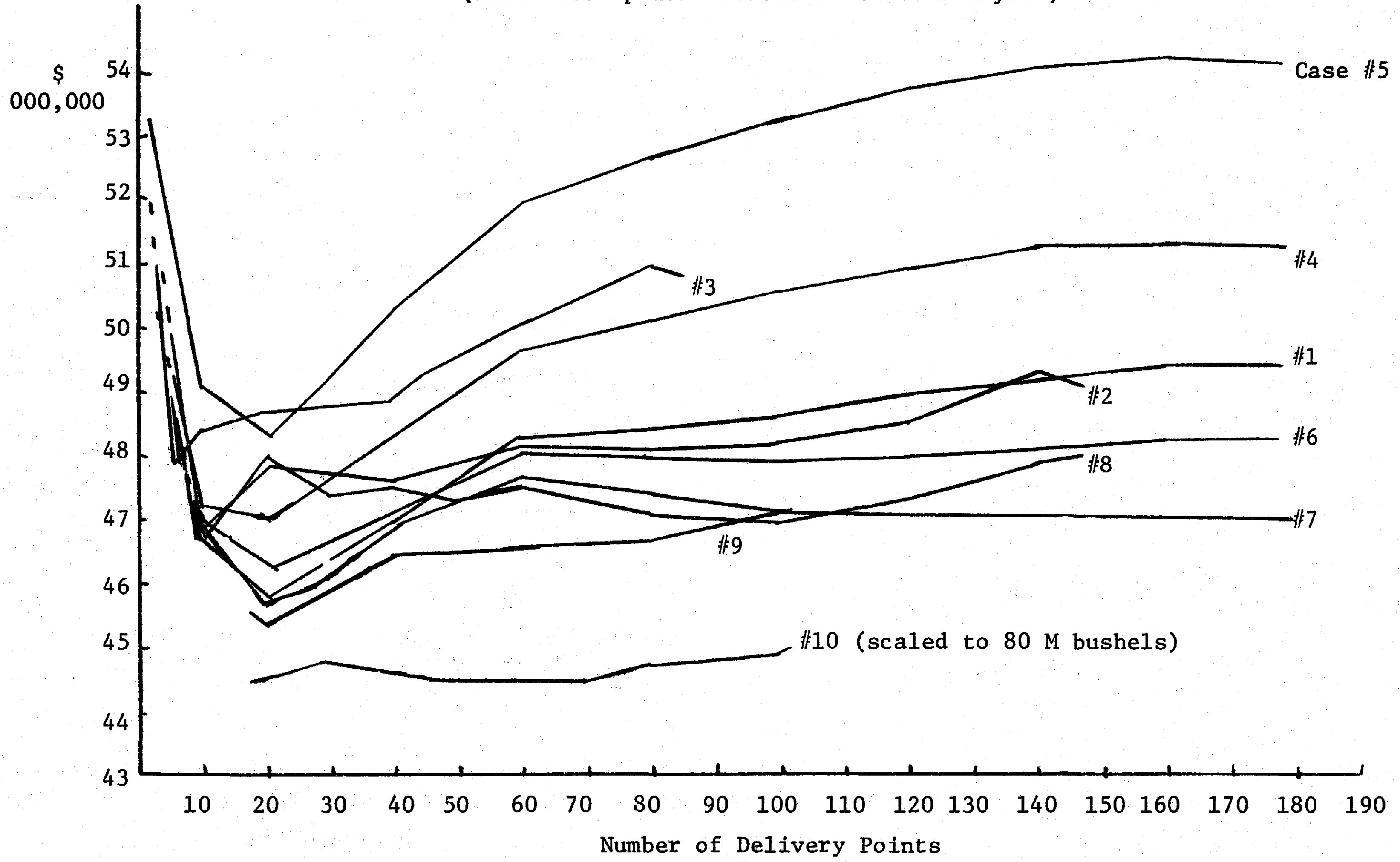
The method used to account for rail costs has a major impact on the number of points required. The rail cost option indicated fewer points were required than did the Crow rate option. The Crow rate was approximately constant over the range of delivery points therefore it had little centralizing influence. The rail cost in contrast, varied with the number of delivery points and therefore had a centralizing effect.

The number of delivery points required to serve the grain collection system at minimum cost depends on elevator efficiency at each point. Given duplication and inefficient use of the present elevators at existing points fewer points would concentrate activity, and thereby increase the operational efficiency of the remaining points and elevators. When duplication is avoided more points are required and the saving from closing any of the present delivery points is reduced.

Closure of rail branch lines was considered to a limited extent. Results indicate that closure of some light traffic density branch lines would reduce collection costs. In cases where abandonment was not specifically considered there were a number of branch lines on which

Figure 6.2

Total Cost of Grain Collection in the Study Area
As a Function of the Number of Collection Points
(Rail Cost Option for the 10 Cases Analyzed)



Source: Calculated from optimal solutions.

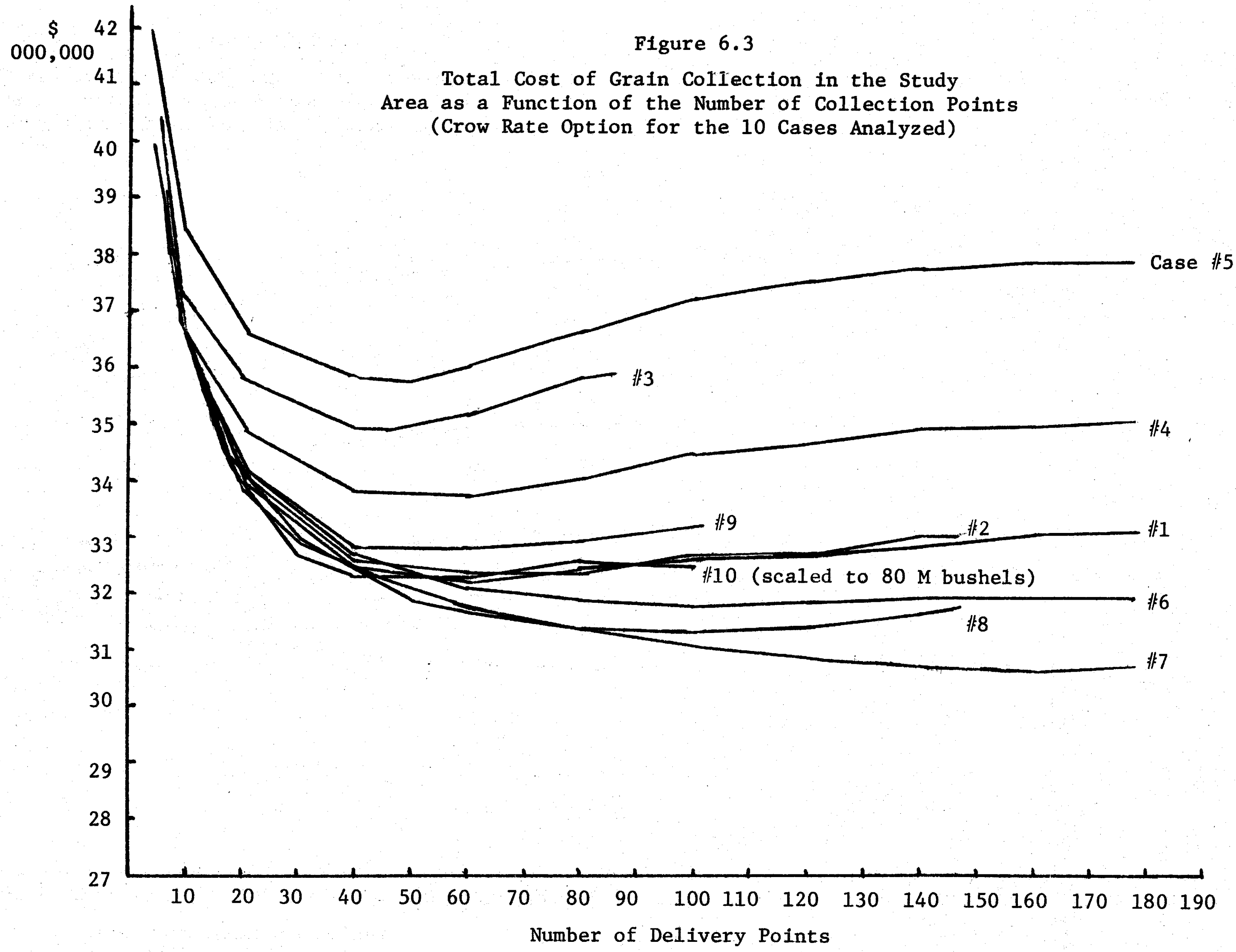


Figure 6.3

Total Cost of Grain Collection in the Study Area as a Function of the Number of Collection Points (Crow Rate Option for the 10 Cases Analyzed)

Source: Calculated from optimal solutions.

no points were operational, particularly for the rail cost option when the optimum number of points for the study area approximated 15 percent of the total points available.

Any increase in grain deliveries would require more delivery points to provide service at least cost. The assembly cost increase would be minimized with little affect on the rail component as more points were operated on existing lines.

Centralization of the system would re-allocate costs from elevator and rail to farm storage, trucking and road components. The increased burden of trucking is distributed on the basis of change in delivery distance.

Indications are that a highly centralized system would increase the total cost of grain handling and transportation. A highly centralized system in terms of the area study ranges up to 5 delivery points or on a province basis up to 25 points.

6.3 Implications and Need For Further Research

In all the cases tested the saving to the system that lead to fewer delivery points was less than the saving in the elevator component. The elevator saving resulted from handling the same amount of grain through fewer elevators. If elevators are operated efficiently and there is a profit to be made on present tarrifs competing firms would in theory be expected to build elevators until the profit level on their operations reach zero. If so, will they then apply for increased tarrifs? Alternately, if firms do not compete at individual sites what will ensure pricing efficiency to the grain producer? The trade-off between market and technical efficiency (section 3.7) needs to be explored.

Because charges of elevator companies to grain producers are largely regulated the opportunity for exploitation at individual delivery points exists primarily on the service side of their operations.

Inflation and methods to avoid rising costs is a major impetus to changing the grain collection system. The implications for the system when inflation has a greater impact on one component as opposed to another was not analyzed. For example, a high inflation rate on fuel will have a greater impact on a grain collection system with few delivery points than on a system with many points because trucks consume more fuel per bushel mile than do trains. Analysis of inflation is required before recommending changes that will shift the cost burden, particularly since road and railroad cost estimates were based on less than complete information.

The Crow rate because it was approximately constant over the number of delivery points considered was decentralizing in relation to the rail cost option. The feature is not necessarily peculiar to the Crow's Nest Pass rate, it would apply equally well to any rate applied in a similar uniform manner. The decentralizing tendency is due to the uniformity of the Crowsnest rate not to its level.

Results from the study suggest that some rail branch lines could be abandoned thereby reducing cost. The road costs however were calculated on an aggregate basis and only maintained a road in its present state. Any upgrading of a road or roads due to abandonment of a rail line would have to be specifically weighed against the cost of maintaining the rail line. Care must be taken to insure that road and rail costs are treated consistently i.e.: reconcile the accounting of opportunity cost for private (rail) versus public (road) investments.

In addition to the private vs. public aspects of the road-rail trade-off there are federal vs. provincial implications in that roads are a provincial responsibility and railways are a federal responsibility.

The cost of roads is directly related to truck size and truck size is dependent on centralization of the grain collection system. Large farm trucks are more expensive in terms of road use than are semi-trailers and both much more expensive than small farm trucks.

In addition to road costs, the cost of farm storage was identified on an aggregate basis only. An indepth analysis of these components would be required to determine the full local impact of closure or upgrading of individual delivery points. If the bulk of the increase in road and farm storage cost falls on the same locations that the increase in trucking cost does (section 5.2) then some locations will experience an absolute as well as relative increase in the cost of grain collection. The impact of a change from relatively equal competitive position for producers in a decentralized system to a relatively unequal position in a centralized system requires investigation.

Service and community impact analysis can be considered in light of the savings indicated <u>likely</u> to result from centralization of the grain collection system. Are grain producers willing to pay a minimum of 1-2¢/bushel to maintain "competition" at grain delivery points? Is the benefit to a small community of maintaining its status as a grain collection point worth the <u>potential</u> 5¢/bushel saving? Are there any changes in service or function of a country elevator that would offset the potential saving from centralization?

Application of the model and solution procedure were limited to a few basic cases which only begin to tap the potential information that can be obtained from the model. The model was designed to provide as much flexibility as possible given time and financial constraints however it could undoubtedly benefit from improved specification of its components and more precise and detailed data.

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APPENDIX "A"

This appendix contains data describing the delivery points in the study area for 1974. The ten year average handling and elevator capacities were obtained from Canadian Grain Commission publications. The average hauling distance and average farm deliveries were obtained from information gathered for the Canada Grains Council Area 11 Study. The delivery points are identified by the rail line on which they are located.

Table A.1

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
1	Saskatoon	CN #1	144	--	51.2	3,069
2	Grandora	CN #1	134	56	7.0	4,516
3	Asquith	CN #1	599	188	9.2	5,343
4	Kinley	CN #1	404	183	11.1	4,679
5	Leney	CN #1	181	60	7.8	4,974
6	Biggar	CN #12	1,373	704	14.5	6,311
7	Landis	CN #12	1,056	482	10.2	8,530
8	Redford	CN #12	306	92	6.8	9,860
9	Scott	CN #12	428	170	8.5	8,323
10	Unity	CN #12	1,092	474	11.6	8,389
11	Highgate	CN #8	181	89	5.6	7,004
12	Delmas	CN #8	279	151	7.2	6,940
13	Paynton	CN #8	393	116	5.9	4,970
14	Maidstone	CN #8	1,116	597	11.0	6,359

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
15	Waseca	CN #8	622	261	8.6	7,164
16	Lashburn	CN #8	1,037	577	8.8	7,445
17	Marshall	CN #8	543	263	6.9	4,899
18	Lloydminster	CN #8	378	186	13.4	3,874
19	Fairmont	CN #9	259	94	5.0	12,083
20	Pinkham	CN #9	295	116	5.4	13,998
21	Flaxcombe	CN #9	475	164	8.3	10,290
22	Marengo	CN #9	685	265	8.2	10,399
23	Alsask	CN #9	288	120	6.6	10,260
24	Vanscoy	CN #5	345	164	7.2	7,987
25	Delisle	CN #5	608	338	8.2	6,869
26	Laura	CN #5	344	105	6.6	9,113
27	Tessier	CN #5	327	189	7.8	9,904
28	Harris	CN #5	714	497	8.8	11,045

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
29	Zealandia	CN #5	780	453	7.1	11,600
30	Rosetown	CN #5	792	426	13.9	8,608
31	Ridpath	CN #5	61	39	5.6	10,758
32	Fiske	CN #5	575	238	8.1	10,079
33	D'Arcy	CN #5	394	149	6.3	8,568
34	Brock	CN #5	748	307	11.4	8,459
35	Netherhill	CN #5	585	264	6.0	14,360
36	Beadle	CN #5	565	159	7.0	11,358
37	Kindersley	CN #5	1,484	761	14.5	9,021
38	Beechy	CN #2	1,294	647	9.1	12,389
39	Demaine	CN #2	519	228	7.0	8,235
40	Lucky Lake	CN #2	893	346	9.0	10,264
41	Tullis	CN #2	239	51	4.5	12,212
42	Birsay	CN #2	517	139	8.9	8,911

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (mile)	Av. Farm Deliveries (bushel)
43	Dunblane	CN #2	223	148	8.4	6,819
44	Macrorie	CN #29	280	106	6.5	7,882
45	Denny	CN #29	214	67	4.7	8,401
46	Ardath	CN #29	355	151	8.8	7,558
47	Donovan	CN #29	252	122	5.3	6,033
48	Glidden	CN #4	617	408	9.2	11,521
49	Madison	CN #4	734	505	7.2	15,456
50	Snipe Lake	CN #4	682	353	7.3	11,117
51	Dinsmore	CN #4	1,094	644	10.2	9,124
52	Wiseton	CN #4	648	343	12.3	6,917
53	Forgan	CN #4	530	501	8.2	10,172
54	Hughton	CN #4	564	311	11.6	8,919
55	Elrose	CN #4	697	392	11.9	9,009
56	Wartime	CN #4	364	157	6.0	13,025

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
57	Plato	CN #4	504	203	6.5	12,090
58	Richlea	CN #4	779	451	8.7	14,838
59	Eston	CN #4	1,102	641	11.5	7,762
60	White Bear	CN #11	676	294	7.5	8,780
61	Lacadena	CN #11	460	220	6.4	10,495
62	Tyner	CN #11	479	247	5.9	11,966
63	Isham	CN #11	442	274	6.3	8,769
64	Mantario	CN #10	756	407	7.8	12,129
65	Laporte	CN #10	1,062	584	9.0	12,338
66	Eatonia	CN #10	913	476	8.6	10,139
67	Battleford	CN #8	509	363	13.8	4,343
68	Lett	CN #15	165	27	5.3	6,923
69	Salter	CN #15	122	79	6.4	6,260
70	Cando	CN #15	476	170	9.9	6,888

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
71	Duperow	CN #14	244	76	6.9	5,820
72	Springwater	CN #14	336	92	5.1	7,614
73	Ruthilda	CN #14	333	96	7.2	9,115
74	Downe	CN #14	230	107	5.5	9,134
75	Dodsland	CN #14	656	220	8.2	7,583
76	Millerdale	CN #14	264	78	5.6	10,654
77	Beaufield	CN #14	329	107	6.6	11,628
78	Coleville	CN #14	658	190	7.0	11,375
79	Smiley	CN #14	428	127	6.2	8,326
80	Dewar Lake	CN #14	343	99	6.4	8,454
81	Loverna	CN #14	249	74	6.3	6,524
82	Cosine	CN #13	145	66	5.2	6,578
83	Cactus Lake	CN #13	594	148	6.7	7,475
84	Hearts Hill	CN #13	485	174	7.9	7,931

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
85	Reward	CN #13	598	280	7.0	8,517
86	Lloydminster	CP #16	302	162	13.4	3,874
87	Lone Rock	CP #16	202	89	5.1	5,286
88	Marsden	CP #16	584	399	7.7	6,541
89	Neilburg	CP #16	520	252	8.8	5,686
90	Baldwinton	CP #16	411	209	9.0	6,369
91	Wilbert	CP #16	353	170	8.4	6,063
92	Cut Knife	CP #16	511	246	7.9	8,637
93	Rockhaven	CP #16	873	345	9.9	9,743
94	Cloan	CP #16	300	105	6.2	8,640
95	Thackeray	CP #16	241	124	7.1	9,923
96	Phippen	CP #17	315	168	5.2	12,046
97	Adenac	CP #17	286	125	6.4	8,993
98	Unity	CP #17	533	187	11.6	8,389

Table A.1 Continued

Point Number	Point Name	Rail	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
99	Rutland	CP #17	209	95	6.5	5,389
100	Senlac	CP #17	425	203	6.7	6,479
101	Evesham	CP #17	301	159	6.2	9,087
102	Macklin	CP #17	703	279	8.5	8,567
103	Wilkie	CP #18	961	470	11.1	9,429
104	Biggar	CP #18	262	132	14.5	6,311
105	Perdue	CP #18	417	151	9.3	4,694
106	Saskatoon	CP #18	928	1,365	51.2	3,069
107	Primate	CP #20	439	163	6.1	6,614
108	Denzil	CP #20	623	242	6.8	7,166
109	Salvador	CP #20	498	214	6.3	9,724
110	Luseland	CP #20	1,476	540	9.6	10,840
111	Kerrobert	CP #20	864	405	9.6	8,481
112	Druid	CP #19	322	115	6.5	8,586

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
113	Plenty	CP #19	731	261	7.6	11,045
114	Stranraer	CP #19	452	222	5.9	10,705
115	Herschel	CP #19	1,008	454	9.2	9,993
116	Anglia	CP #19	218	101	5.3	9,801
117	Rosetown	CP #19	993	861	13.9	8,608
118	Fortune	CP #19	195	151	4.0	11,516
119	Sovereign	CP #19	555	329	6.0	13,652
120	Milden	CP #19	781	428	6.8	13,652
121	Bounty	CP #19	290	147	6.4	10,333
122	Conquest	CP #19	297	180	6.6	7,763
123	Rex	CP #21	161	121	7.9	3,443
124	Hillmond	CP #21	221	155	6.0	3,337
125	Greenstreet	CP #21	242	171	7.7	4,254
126	Revenue	CP #22	394	158	5.3	8,591
127	Tramping Lake	CP #22	688	223	5.6	8,693

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
128	Broadacres	CP #22	317	75	4.5	8,040
129	Superb	CP #23	464	169	7.4	10,937
130	Major	CP #23	482	162	7.9	8,257
131	Fusilier	CP #23	180	51	7.7	4,544
132	Leipzig	CP #24	383	129	4.9	9,388
133	Handel	CP #24	505	169	4.7	11,329
134	Kelfield	CP #24	280	108	6.6	9,397
135	Arelee	CP #25	473	220	6.7	6,749
136	Struan	CP #25	330	125	7.8	6,397
137	Sonningdale	CP #25	300	89	8.4	3,979
138	Marriott	CP #26	328	141	6.5	9,832
139	Valley Centre	CP #26	232	98	7.1	7,415
140	Feudal	CP #26	233	63	5.8	7,573
141	Matador	CP #27	245	103	4.9	12,723

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
142	Kyle	CP #27	752	345	9.5	8,106
143	Tuberose	CP #27	259	172	3.9	14,685
144	Sanctuary	CP #27	461	262	8.3	10,856
145	Mondou	CP #27	116	108	3.9	12,822
146	Wartime	CP #27	162	38	6.0	13,025
147	Glamis	CP #28	342	219	4.4	11,184
148	Thrasher	CP #28	235	142	3.7	11,490
149	Gunnworth	CP #28	150	95	3.2	9,111
150	Bickleigh	CP #28	216	100	3.8	12,460
151	Totnes	CP #28	207	143	3.3	9,452
152	McMorran	CP #28	327	144	4.5	9,970
153	Bratton	CN #29	181	50	5.9	8,141
154	Ibstone	CN #15	162	97	7.3	4,343
155	Tatsfield	CN #30	136	56	6.3	6,216

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
156	Gallivan	CN #30	154	86	6.0	7,300
157	Prongua	CN #30	244	109	7.3	5,821
158	Hoosier	CN #14	162	66	6.0	7,489
159	Driver	CN #14	197	47	3.8	9,851
160	Argo	CN #14	78	50	6.0	6,066
161	Sunnyglen	CN #13	173	112	5.7	8,453
162	Dankin	CN #10	179	52	4.8	10,830
163	Sandgren	CN #4	142	28	4.7	10,271
164	Witley	CN #11	132	95	5.5	8,266
165	Leach Siding	CN #4	265	92	6.6	8,021
166	Anerley	CN #4	317	94	5.4	8,763
167	Bresaylor	CN #12	175	116	6.6	5,955
168	Winter	CN #12	105	52	6.2	5,879
169	Vera	CN #12	113	50	5.9	6,889

Table A.1 Continued

Point Number	Point Name	Rail line	10 year av. Deliveries (000)	Elevator Capacity (000)	One Way av. Dist. (miles)	Av. Farm Deliveries (bushel)
170	Tako	CN #12	147	38	5.5	8,356
171	Cavell	CN #12	158	51	6.2	9,195
172	Oban	CN #12	89	52	5.4	7,421
173	Cazalet	CN #1	156	43	6.3	5,643
174	Bents	CP #26	212	101	6.3	7,479
175	Catherwood	CP #26	172	71	6.6	6,274
176	Environ	CP #25	194	81	6.9	6,046
177	Baljennie	CP #25	162	56	7.4	4,161
178	Wolfe	CP #18	60	50	5.0	8,060
179	Traynor	CP #18	113	54	5.3	7,395
180	Keppel	CP #18	115	70	6.4	5,643
181	Furness	CP #16	255	127	7.9	4,580
182	Merid	CN #9	177	49	5.0	10,330
183	McGee	CN #5	119	50	4.6	10,419

APPENDIX "B"

This Appendix contains data describing the rail ines in the study area. The data on mileage for each segment and on line capital cost allowance were obtained from information provided by the Canadian Transport Commission for the year 1974.

Table B.1

Rail line	Mileage	On-line capital cost allowance (1974) $/mile	CN	CP	Branch	Basic
#1 Watrous	55.7	2,690*	X			X
#2 Conquest-Beechy	35.0	1,307	X		X	
#4 Elrose	120.7	1,212	X		X	
#5 Rosetown	121.3	1,751	X			X
#8 Blackfoot	92.2	2,690*	X			X
#9 Oyen	48.0	3,279	X			X
#10 Mantario	43.8	1,257	X		X	
#11 White Bear	34.3	1,106	X		X	
#12 Wainwright	100.0	2,690*	X			X
#13 Bodo	51.5	1,327	X		X	
#14 Dodsland	104.2	1,027	X		X	
#15 Porter	43.9	731	X		X	
#16 Lloydminster	104.6	2,355		X		X
#17 Hardisty	56.4	2,067*		X		X

Table B.1 Continued

Rail line	Mileage	On-line capital cost allowance (1974) $/mile	CN	CP	Branch	Basic
#18 Wilkie	99.6	2,067*		X		X
#19 Kerrobert	102.5	1,914		X		X
#20 Macklin	46.4	1,793		X		X
#21 Big Gully	24.4	1,779		X	X	
#22 Reford	42.8	1,481		X	X	
#23 Coronation	46.5	1,665		X	X	
#24 Kelfield	27.9	1,594		X	X	
#25 Asquith	43.9	1,941		X	X	
#26 Rosetown	44.7	1,664		X	X	
#27 Matador	43.1	2,107		X	X	
#28 McMorran	61.6	2,153		X	X	
#29 Conquest	59.3	918	X		X	
#30 Cut Knife	26.8	1,075	X		X	

* Estimated allowance for these lines, as no claim for subsidy was made for them. The exact figure was not available.

APPENDIX "C"

This appendix contains the size and age of each elevator by delivery point in the study area for 1974 and the Crow's Nest Rate for each delivery point. The size and age information was obtained from material complied by the Canadian Grain Commission.

Table C.1

Delivery Point	Elevator size in bushels / Age in years (1974 = 1)					Crow Rate (¢/cwt.) Vancouver	Crow Rate (¢/cwt.) Thunder Bay
1	66,000	107,000	30,000	41,000		24	22
	7	23	47	49			
2	30,000	26,000				24	22
	46	59					
3	165,000	23,000				24	22
	7	40					
4	135,200	48,000				24	23
	7	57					
5	33,000	27,000				24	23
	59	58					
6	365,000	105,000	124,000	132,000	110,000	24	23
	9	12	14	53	65		
7	161,900					24	23
	10						
8	92,000					23	23
	46						
9	90,000	80,000				23	23
	15	29					
10	98,000	111,000	77,200	194,500	104,000	23	24
	12	15	47	64	65		

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)			Crow Rate (¢/cwt.)	
						Vancouver	Thunder Bay
10	75,600 66					23	24
11	63,000 47	26,000 52				24	22
12	73,000 48					23	24
13	67,000 16	49,000 47				23	24
14	187,900 20	190,300 36	132,200 47	79,000 54	65,100 61	23	24
	42,800 69						
15	118,000 21	74,000 33	69,000 51			23	24
16	110,300 25	129,600 40	148,200 42	90,300 46	98,700 53	23	24
17	104,000 16	74,000 53	85,000 64			23	24
18	94,500 8	162,000 12	91,000 46			23	24

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)		Crow Rate (¢/cwt.)	
					Vancouver	Thunder Bay
19	64,000 14	29,500 50			24	24
20	65,000 15	51,000 58			24	24
21	47,000 18	55,100 46	28,000 58	33,600 59	24	24
22	92,000 10	113,000 22	60,000 57		24	24
23	62,000 8	29,700 47	27,900 69		24	24
24	43,000 53	28,000 57	47,000 59	46,000 64	24	22
25	85,000 49	113,000 58	111,000 67	29,000 46	25	22
26	82,000 31	23,000 66			25	23
27	98,000 18	91,000 57			25	23
28	170,400 27	211,000 47	115,300 60		25	23

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)			Crow Rate (¢/cwt.)	
						Vancouver	Thunder Bay
29	136,400	93,200	133,900	89,400		25	23
	12	18	66	66			
30	289,700	195,800	102,300	151,800	99,800	25	23
	10	13	13	43	45		
	215,000	223,500					
	47	57					
31	39,000					25	23
	52						
32	101,400	137,000				25	23
	16	61					
33	103,000	45,600				25	23
	47	53					
34	141,600	99,200	66,100			25	24
	8	18	65				
35	69,000	113,000	82,000			24	24
	20	65	61				
36	88,600	70,700				24	24
	21	60					

Table C.1 Continued

Delivery Point	Elevator size in bushel	Age in years (1974 = 1)				Crow Rate (¢/cwt.)	
						Vancouver	Thunder Bay
37	145,000 10	140,000 10	126,100 11	134,000 39	95,000 41	24	24
	121,000 61						
38	123,000 19	128,000 46	99,000 47	92,000 53	81,000 53	26	24
	124,000 54						
39	107,000 47	89,300 52	32,000 53			26	24
40	119,000 19	95,000 47	91,400 55	40,500 55		26	24
41	51,000 17					26	24
42	87,300 55	52,100 55				26	23
43	93,000 59	55,000 50				26	23
44	26,000 59					25	23

Table C.1 Continued

Delivery Point	Elevator size in bushel Age in years (1974 = 1)					Crow Rate (¢/cwt.)	
						Vancouver	Thunder Bay
45	67,000 46					25	23
46	81,000 19	70,000 56				25	23
47	52,000 39	38,000 61	32,000 63			25	23
48	85,000 21	165,000 58	85,200 57	72,500 60		24	24
49	160,000 17	113,000 58	68,500 58	58,000 58	105,000 62	24	24
50	105,000 21	85,000 23	73,000 58			24	24
51	181,900 9	103,000 16	92,000 19	201,000 58	66,000 58	26	23
52	108,000 17	57,100 46	72,800 58	66,300 59	38,900 63	25	24
53	122,000 35	237,000 62	71,000 61	92,000 63		25	24
54	89,400 38	149,000 63	26,000 48	46,400 62		25	24

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)			Crow Rate (¢/cwt.) Vancouver	Thunder Bay
55	126,000	105,000	63,000	98,000		25	24
	14	60	43	62			
56	82,000	38,000	76,700			25	23
	22	46	60				
57	113,000	90,100				25	24
	14	60					
58	134,000	127,000	65,000	125,000		25	23
	12	16	35	58			
59	124,000	126,000	125,000	134,100	132,000	25	24
	23	28	30	42	60		
60	127,000	102,000	65,000			25	25
	25	48	50				
61	85,000	87,000	48,000			25	24
	47	49	49				
62	85,000	85,500	76,000			25	24
	49	50	49				
63	125,500	77,000	71,000			25	24
	49	47	50				
64	90,000	142,000	107,000	68,000		24	24
	7	47	55	55			

Table C.1 Continued

Delivery Point	Elevator size in bushel / Age in years (1974 = 1)					Crow Rate (¢/cwt.) Vancouver	Crow Rate (¢/cwt.) Thunder Bay
65	90,000 7	122,000 47	107,800 51	125,000 53	139,000 57	24	24
66	125,000 16	90,000 47	136,000 56	125,000 56		24	24
67	185,000 8	178,000 15				24	24
68	27,000 47					24	23
69	29,000 47	50,000 47				24	23
70	98,000 58	71,700 64				24	23
71	76,000 46					24	23
72	67,000 17	25,000 49				24	23
73	49,000 49	46,800 49				24	23
74	62,000 48	45,100 59				24	23

Table C.1 Continued

Delivery Point	Elevator size in bushel Age in years (1974 = 1)			Crow Rate (¢/cwt.) Vancouver	Thunder Bay
75	122,000 16	72,000 51	26,000 50	24	24
76	78,000 15			24	24
77	67,000 60	39,500 60		24	24
78	92,000 35	71,900 58	26,000 50	24	24
79	27,000 36	45,000 51	55,000 54	24	24
80	50,000 15	49,000 54		25	24
81	74,000 45			25	24
82	38,000 44	28,000 44		24	24
83	67,000 43	54,800 44	26,000 44	24	24
84	101,000 44	73,000 44		23	24

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)		Crow Rate (¢/cwt.)	
					Vancouver	Thunder Bay
85	75,000	75,000	85,000	45,000	23	24
	43	44	45	49		
86	94,500	162,000	91,000		23	24
	8	12	46			
87	63,000	26,000			25	24
	49	49				
88	65,300	79,000	73,800	42,900	25	24
	43	51	52	51		
89	118,000	74,000	80,000		25	24
	51	50	51			
90	125,000	84,000			24	24
	8	52				
91	91,000	54,000	25,000		24	24
	52	52	52			
92	124,000	77,000	45,200		24	24
	27	45	60			
93	163,000	134,000	48,000		24	24
	60	63	47			
94	63,000	20,700	21,000		25	24
	48	60	63			

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)			Crow Rate (¢/cwt.)	
						Vancouver	Thunder Bay
95	83,000 16	41,000 47				25	23
96	104,000 45	64,000 50				23	23
97	63,000 46	62,000 48				23	24
98	98,000 12	111,000 15	77,200 47	194,500 64	104,000 65	23	24
	75,600 66						
99	41,000 47	27,000 47	27,000 58			24	24
100	25,000 47	84,000 64	71,200 62	23,000 59		24	24
101	47,700 52	86,000 62	25,000 59			24	24
102	76,000 23	121,000 38	90,400 55	32,000 59		24	24
103	165,000 7	230,000 20	75,000 53			23	23

Table C.1 Continued

Delivery Point	Elevator size in bushel	Age in years (1974 = 1)				Crow Rate (¢/cwt.)	
						Vancouver	Thunder Bay
104	365,000	105,000	124,000	132,000	110,000	24	23
	9	12	14	54	65		
105	100,900	50,000				24	23
	8	17					
106	1,121,000	66,000	107,000	30,000	41,000	24	22
	4	7	23	47	49		
107	50,000	67,000	46,300			24	24
	15	57	62				
108	136,000	82,300	24,000			23	24
	9	60	60				
109	112,000	101,500				23	24
	28	47					
110	150,000	117,000	70,000	45,000	93,500	24	24
	8	23	49	49	57		
	64,400						
	63						
111	181,000	170,000	54,300			24	24
	7	9	63				
112	94,000	21,000				24	24
	18	62					

Table C.1 Continued

Delivery Point	Elevator size in bushel Age in years (1974 = 1)					Crow Rate (¢/cwt.) Vancouver	Thunder Bay
113	90,000 15	98,000 60	73,100 65			24	23
114	88,000 46	65,000 64	47,000 63	22,000 63		25	23
115	150,000 9	78,000 28	90,100 37	136,000 47		25	23
116	54,000 47	24,000 60	23,000 63			25	23
117	298,700 10	191,800 13	702,300 13	151,800 43	99,800 45	25	23
	215,000 47	223,500 57					
118	72,000 20	78,700 60				25	23
119	99,000 12	58,000 45	95,900 63	76,000 64		25	23
120	112,500 46	121,000 62	97,100 64	71,000 64	26,000 63	25	23
121	46,000 50	78,000 63	23,000 52			25	23

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)			Crow Rate (¢/cwt.)	
						Vancouver	Thunder Bay
122	78,000	72,000	30,000			25	23
	10	18	63				
123	59,000	62,000				25	24
	28	46					
124	89,000	66,000				25	25
	45	47					
125	95,000	76,000				25	25
	30	46					
126	67,000	25,000	20,800	23,000	22,000	25	24
	53	47	58	60	62		
127	95,000	80,500	27,000	22,000		25	24
	46	62	47	62			
128	48,000	26,500				24	24
	19	37					
129	111,000	57,600				24	24
	7	60					
130	78,000	84,300				24	24
	11	61					
131	26,000	25,000				24	24
	58	59					

Table C.1 Continued

Delivery Point	Elevator size in bushel / Age in years (1974 = 1)				Crow Rate (¢/cwt.) Vancouver	Crow Rate (¢/cwt.) Thunder Bay
132	61,000	43,000	25,000		23	24
	50	57	62			
133	78,000	26,000	25,000	40,000	25	24
	49	52	58	60		
134	43,000	45,000			24	23
	43	46				
135	89,000	80,000	50,500		26	23
	44	47	48			
136	74,000	51,000			26	23
	47	46				
137	64,000	25,000			26	23
	48	47				
138	46,000	49,000	46,000		25	23
	34	47	47			
139	49,000	49,000			25	23
	47	47				
140	63,000				25	23
	47					
141	70,000	33,000			26	24
	17	52				

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)		Crow Rate (¢/cwt.)	
					Vancouver	Thunder Bay
142	97,800 45	102,000 51	91,000 52	54,000 51	25	24
143	68,000 52	58,000 52	46,300 52		25	24
144	91,000 52	89,000 52	82,000 52		26	24
145	78,000 52	30,000 45			26	23
146	82,000 22	38,000 46	74,700 60		25	23
147	82,400 52	74,800 52	62,000 53		26	23
148	79,000 49	63,000 52			25	23
149	95,000 52				25	23
150	51,000 47	49,000 52			26	23
151	94,000 47	49,000 50			26	23

C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)	Crow Rate (¢/cwt.) Vancouver	Thunder Bay
152	69,000 42	75,000 52		26	24
153	50,000 18			25	23
154	46,000 47	51,000 52		24	23
155	31,000 47	25,000		24	24
156	86,000 58			24	24
157	46,000 53	63,000 58		24	24
158	66,000 61			25	24
159	47,000 63			24	24
160	50,000 61			24	23
161	52,800 43	59,000 45		23	24

Table C.1 Continued

Delivery Point	Elevator size in bushel	Age in years (1974 = 1)		Crow Rate (¢/cwt.)	
				Vancouver	Thunder Bay
162	27,000 47	25,000 51		24	24
163	28,000 47			24	24
164	51,000 47	44,000 50		25	24
165	68,000 49	24,000 47		26	23
166	51,100 48	22,600 46	20,600 62	26	23
167	50,500 37	65,000 47		23	24
168	52,000 37			23	24
169	50,000 51			23	24
170	38,000 44			23	24
171	51,000 49			23	23

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)	Crow Rate (¢/cwt.)	
				Vancouver	Thunder Bay
172	52,000 64			24	23
173	43,000 47			24	23
174	74,000 47	27,000 47		25	23
175	71,000 25			24	23
176	55,000 49	26,000 49		26	23
177	28,000 41	28,000 44		27	23
178	-- --			25	23
179	28,000 43	26,000 52		24	23
180	70,000 18			24	23
181	58,000 49	42,000 47	27,000 49	25	24

Table C.1 Continued

Delivery Point	Elevator size in bushel		Age in years (1974 = 1)	Crow Rate (¢/cwt.)	
				Vancouver	Thunder Bay
182	49,000 47			24	24
183	27,000 48	23,000 64		25	23

APPENDIX "D"

Road costs are presented in this appendix. The costs and servicable life of the roads were based on information available from the Saskatchewan Department of Highways. The allocation of costs is based on axle load weightings. The figure arrived at for the gravel surface is used in the study. Oiled and paved surface costs are presented for comparison.

1. Gravel Surface Road

It was assumed that a gravel surfaced road would require rebuilding at 12 year intervals at a cost of \$12,910 or \$1,075.83 per year. The average daily traffic (ADT) for calculation of cost was 150/day for a 200 day year. The traffic and load factors for each catagory were distributed as follows:

cars 84%, L.F. = .0237

farm trucks 14%, L.F. = .324 (33% loaded)

trucks 2%, L.F. = 1.318 (50% loaded)

The total 18 KIP load factor per day at ADT = 150 is 10.8. The cost per 18 KIP was \$1,075.83/10.8 x 200 = 49.8¢/18KIP/mile. In addition there was a maintenance cost of \$500/mile/year allocated on the basis of vehicle mile. This translates to an added cost of 1.7¢/mile for a total cost of 51.5¢/18KIP/mile.

2. Oil Surface Road

Oil surfaced roads are assumed to require resurfacing every 3 to 5 years depending on traffic at \$14,920 per mile. The maintenance cost also depends on traffic and varies from \$2,000 to \$4,000 per year. When ADT = 150 resurfacing is required every fifth year and maintenance for the 5 years totals \$10,000. This represents a cost of \$4,984/mile/year. When ADT = 300 resurfacing is required every third year and maintenance for the three years total \$12,000. This leads to an annual cost per mile of \$8,973. The traffic and load factors are as follows:

cars 84% , L.F. = .0237

farm trucks 8%, L.F. = .324 (33% loaded)

trucks 8%, L.F. = 1.318 (50% loaded)

The cost per 18 KIP per mile are $1.098 and $.989 for ADT = 150 and 300 respectively. Note that maintenance of the oil surface is allocated on the basis of load factor which was not the case for the gravel surface.

3. Paved Highway Costs

Highways require resurfacing every 12 to 16 years at a cost of $80,000 per mile and require annual maintenance of $2,600 per mile. The cost for ADT = 300 is $6,700/mile/year. When ADT = 600 the cost is $8,314 and when ADT = 1,000 the cost is $9,267. The traffic and loading are assumed as follows:

cars 84%, L.F. = .0237

trucks 12%, L.F. = 1.722 (67% loaded)

farm trucks 4%, L.F. = .324 (33% loaded)

The cost per 18 KIP mile was $.529 at ADT = 300, $.289 at ADT = 600 and $.193 at ADT = 1,000.

APPENDIX "E"

Farm storage costs are based on the method used by Freisen (Freisen). Costs were inflated to 1974 levels using rates obtained from DBS price indices (62-002).

1. Grain Augers

The total cost of using a farm auger was $146.32 which is composed of the following elements:

Depreciation	$ 64.95
Interest on Investment (10%)	35.67
Repairs & Labour	29.37
Fuel	15.83
Insurance	.50
	$146.32

Average farm grain production is 14,166 bushel, 60 percent of which is delivered (8,500 bu.). The cost per bushel is 1.03¢.

2. Farm Storage in Existing Bins

The cost of an average grain bin of 2,147 bushel was $175.59 per year. This cost is composed of the following elements:

Depreciation	$ 63.88
Interest on investment (10%)	34.49
Repairs & Labour	15.07
Insurance	1.67
Grain loss at 0.5%[1/]	46.16
Labour at $4.00/hr.	14.31
	$175.59

This results in a cost of 8.18¢/bushel. When combined with the auger cost the total for farm storage is 9.21¢/bushel.

1/ The standard taken to determine value of loss was $4.30/bushel for Wheat.

3. Farm Storage in New Bins.

It was assumed that new bins would be steel construction equally divided between 1,650 and 2,700 bushel sizes. The cost with wood floors was $948 and $1,336.40 respectively. Depreciation was assumed at 4 percent per annum and interest on investment at 10 percent. The average annual fixed cost per bin was $108.59. Variable costs were assumed to exist at the same level as for existing bins which leads to a total annual bin cost of $185.81 or 8.85¢/bushel. Where a new bin and an auger are costed the total farm storage cost per bushel is 9.88¢.

APPENDIX "F"

This appendix presents the method used to calculate the distance between delivery points in the study area.

The area studied is served by a network of roads which follow a grid and also served by a number of highways which may or not follow the same grid. The distance (d) between two points was calculated from the formula:

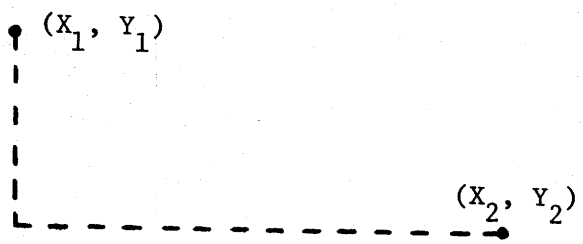
$$d = |X_1 - X_2| + |Y_1 - Y_2| \qquad (F.1)$$

where:

(X_1,Y_1) and (X_2,Y_2) represent the coordinates of the two points in question (Figure F.1).

Figure F.1

Distance Calculation (example)

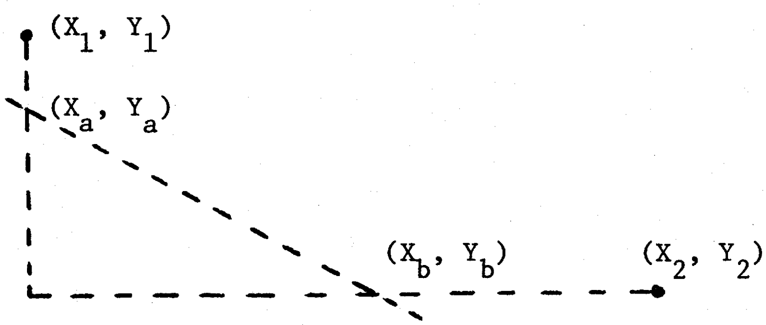


Where highways did not follow the grid a distance saving (ds) was calculated and subtracted from (d) calculated above (Figure F.2).

$$ds = \sqrt{|X_a - X_b|^2 + |Y_a - Y_b|^2} \qquad (F.2)$$

Figure F.2

Distance Saved (example)



More than one ds may be required between two points to approximate linear segments on a highway not following the grid. Where obstructions were encountered such as a lake the distances were adjusted upward to account for the obstruction[1/].

For grain within the area of each point the average distance travelled to that point (the internal distance) was taken from data in the Area 11 Study (Appendix "A"). When a point is closed and grain must be transported to the next open one the following calculations are used.

$$d' = d + .5d'' \qquad \text{(F.3)}$$

where:

d' = the average total distance to be hauled,

d = the distance between open and closed point,

d'' = the internal distance of the closed point.

The formula F.3 is correct for a square area served by a grid network of roads when the delivery point is centered in each area. In some cases the point is not centered in the area as in a case where two points are located near each other. A second calculation is used in this case where the internal distance is large when compared to the distance between points.

$$d' = d'' + .5d \qquad \text{(F.4)}$$

The larger of the two calculations (F.3) or (F.4) is used in the mileage matrix.

1/ In any case where the distance or adjusted distance, whichever the smaller, would have been in excess of 100 miles no corrections were made to the rectangular distance (d).

APPENDIX "G"

This appendix presents the cost functions used in the analytical model.

G.1 Trucking Costs

As noted in Chapter II costs for farm trucking of grain are related to the volume of grain to be moved, size of the truck, and its utilization in grain transportation to the elevator. Since the number of points and their location pattern are both variable in the model the trucking characteristics are also variable. They have been estimated by Kulshreshtha for 1974 conditions as follows:

$$Y = 3.191 - \underset{(8.79)}{.438}\, X_1 - \underset{(9.87)}{.303}\, X_2 + \underset{(15.64)}{.688}\, X_3 - \underset{(7.48)}{.272}\, X_4 + \underset{(8.08)}{.342}\, X_5$$

$$- \underset{(20.65)}{.825}\, X_6 \qquad (G.1)$$

$$R^2 = .756$$

where:

Y = cost/bushel/mile,[1/]

X_1 = size of the grain box,

X_2 = total annual mileage,

X_3 = total bushel delivered per farm

X_4 = age of the truck,

X_5 = one way distance to the elevator,

X_6 = bushels x miles

The observations for grain deliveries (X_3) in equation G.1 are taken from data in the Area 11 study (Appendix "A"). Distance to the elevator (X_5) is calculated as previously described (pp. 163). Annual truck mileage (X_2) was estimated as follows:

1/ All variables are expressed in common logarithms.

$$Y = 918.79 + \underset{(5.21)}{.107}\ X_1 + \underset{(6.68)}{125.62}\ X_2 \qquad \text{(G.2)}$$

$R^2 = .557$

where:

Y = annual mileage,

X_1 = grain deliveries (bushels),

X_2 = miles to the elevator

Observations for size (X_1) and age (X_4) were calculated using logit functions (Kulshreshtha, May, 1975, pp. 302-308) holding variables X_3 (dependence on grain) and X_4 (age of the farmer) at their respective means. The size function is calculated as follows:

$$\begin{array}{ll} \text{Small truck} & 5.004 - 1.594\ X_1 - .925\ X_2 + 785\ X_3 \\ \text{Medium truck} & .655 + .318\ X_1 - .535\ X_2 - 1.007\ X_3 \\ \text{Large truck} & -6.304 + .919\ X_1 + .998\ X_2 + .895\ X_3 \end{array} \qquad \text{(G.3)}$$

where:

X_1 = volume of grain delivered[2/],

X_2 = one way distance to the elevator,

X_3 = dependence on grain

A small truck carries between 75 and 150 bushels of grain with an average of 112. The medium truck carried from 151 to 225 bushels, averaging 188 and a large truck carries from 251 to 350, averaging 288 bushels. The probability for each size of truck is established for each point and from each to every point in the area. The expected truck size for a particular combination (source and destination) is found by

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2/ All variables are expressed in common logarithms.

multiplying the probability of each truck by its mean size and summing.

The age of a truck is calculated in a similar fashion to the calculation of its size using the following:

$$\begin{aligned} &\text{New truck} \quad - 2.510 + .888\ S_1 + 1.105\ S_2 - 1.434\ X_4 \\ &\text{Medium truck} - \ 5.190 + .425\ X_1 + .069\ X_2 + 1.816\ X_4 \qquad \text{(G.4)} \\ &\text{Old truck} \quad + 3.877 = .791\ X_1 - .911\ X_2 - .136\ X_4 \end{aligned}$$

where:

X_4 = the age of the farmer.

A new truck ranges from 1 to 9 years old averaging 4.5 years. A medium truck ranges from 10 to 18 years, averaging 13.5 years and an old truck is in excess of 18 years, averaging 22 years. The expected age of a truck for a particular source-destination combination is obtained by multiplication of each probability by the mean of the category and summing.

The method of calculating trucking cost in equation (G.1) applies to all one way distances between farm and elevator of 40 miles or less. Where the distance is greater than 40 miles it is assumed that grain will be delivered in semi-trailer trucks carrying 775 bushels per load. The cost for hauling by trailer was estimated in the Area 11 study (p.59) as follows:

$$Y = 3.62 + .2166\ X \qquad \text{(G.5)}$$

$$R^2 = .993$$

where:

Y = cost in cent per hundred weight[3/],

[3/] The conversion to bushel from hundred weight is based on an average 56 pound bushel.

X = distance in miles (one way).

An additional 4.5 cents per hundred weight was added for farm pick up.

G.2 Road Costs

The procedure for estimating road costs follows from the trucking cost estimation. The size of truck and the average distance that it travels are known for all combinations of source and destination. Total deliveries from each source are known. By combining these factors the number of loads, size and distance of each can be calculated.

It has been determined (Chapter II, Section 6) that the use of a road by a vehicle is related to its axle loading which is expressed in 18 KIP equivalents; i.e., an 18 KIP axle load has a load factor (L.F.) = 1.0. For a given road surface an estimation is made of the number of 18 KIP axle loads it can sustain before being rebuilt. This leads to a cost per truck mile when the truck loading is expressed in terms of the load factor. The formulae used to calculate these load factors are:

for a single axle

$$L.F. = 10^{(0.12088\ (L-18))} \qquad (G.6)$$

and for a tandem axle

$$L.F. = 10^{(0.12088\ \frac{(1.14L)}{2} - 18)} \qquad (G.7)$$

where:

L = axle load in (000) pounds.

These formulae are used to calculate the weighted factors for loaded grain trucks in each size category. The load factor for a small farm truck was .095, for a medium farm truck .319, for a large farm truck 2.160 and for a semi-trailer 2.508.

Three types of roads are costed using this method for allocating costs. The cost per 18 KIP axle load per mile for a gravel surface was 51.5¢, 98.9¢ for an oil surface and 28.9¢ for a paved surface[4/]. The figure for a gravel surface is used in this study because it represents 85 percent of the total road surface. Oil surfaces are more costly but represent a small portion of the total. Paved roads are cheaper to travel on but again the mileage is limited. The costs presented here only maintain a road in its present condition. Added construction costs to improve a gravel road to paved would amount to 39.7¢ per 18 KIP mile in addition to the 28.9¢ for the first 12 to 16 years of the surface life.

The method of costing roads used in grain transportation has limitations. Costs vary with the road surface and average daily traffic, neither of which is known in advance because of the wide range of delivery patterns contemplated in the model. The incidence of the burden of costs is also unknown but certainly some municipalities will be affected more than others. The cost estimate here is an aggregate figure for the area.

G.3 Country Elevator Costs

The cost of operating a country elevator is dependent principally on its handling to capacity ratio and on its size (Zasada and Tangri, pp. 88 - 91). The cost of operating country elevators in Area 11 was estimated for 1974 as follows:

[4/] See Appendix "D" for details of the road cost estimates.

$$Y = .388 - \underset{(25.28)}{.587}\, X_1 + \underset{(12.73)}{.383}\, X_2 \qquad \text{(G.8)}$$

$R^2 = .699$

where:

Y = cost per bushel handled,

X_1 = receipts,

X_2 = capacity[5/].

This equation estimates the cost of operating country elevators as they existed in 1974 in the area.

A second function was used to provide an estimate for similar facilities which were new. The estimating equation is based on 1973 costs (C.G.C., 1975, p. 85) to which a 15 percent inflation factor was added for 1974.

$$Y = .958 - .765\, X_1 + .482\, X_2 \qquad \text{(G.9)}$$

$R^2 = .916$

where:

Y = cost per bushel handled,

X_1 = receipts,

X_2 = capacity[6/].

The handling to capacity ratio for country elevators was limited in the model to 6:1, a feasible maximum (Zasada and Tangri, Table XV, p. 79). In addition to the handling constraint a minimum cost of

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5/ All variables are expressed in common logarithms.

6/ All variables are expressed in common logarithms.

operating new facilities is set at 8.043¢ per bushel handled.[7/]

In cases where existing elevators are costed the grain arriving at a point is divided among elevators into portions reflecting their relative capacities. In cases where facilities are replaced and a competitive situation is assumed two facilities of equal size and handling are costed. No competition is assumed for a point where new facilities are built if the total handling is less than 300,000 bushels.

G.4 Railway Costs

Railway costs are determined in three ways. Where the Crow's Nest Rates are assumed (Appendix "C") grain is delivered from each point to Thunder Bay and Vancouver in equal proportions. The rate east and west is used for individual country elevator points. Second, rail costs were determined for 1974 using information submitted by the railways to the Canadian Transport Commission for subsidy payments under Sections #256 and #258 of the Railway Act (Appendix "B"). Regression analysis provided the following estimate:

$$Y = 458.06 - \underset{(2.55)^{8/}}{4.432}\,X_1 + \underset{(3.03)}{.234}\,X_2 + \underset{(2.10)}{136.45}\,X_3 - \underset{(1.75)}{104.83}\,X_4 \qquad \text{(G.10)}$$

$$R^2 = .598$$

7/ This figure is the estimated cost of handling grain in a new elevator having a capacity of 300,000 bushel and handling 1,800,000 annually. Inland terminals and high throughput elevators are not specifically considered in this model but their cost efficiency is not anticipated to be any better than this level. Kulshreshtha (Kulshreshtha, April, 1975, Table III, p. 5) estimated costs for an inland terminal handling 10:1 would cost 8.6¢ per bushel handled.

8/ A T value of 2.145 represents the 5% significance level.

where:

Y = cost in dollars per carlot[9/],

X_1 = grain density per mile of track,

X_2 = on-line capital cost allowance,

X_3 = CN, CP,

X_4 = basic, branch line.

The final method for calculating rail costs is based on the second. A constant cost allotment (X_2) of $3,500 per mile of track is assumed which represents an hypothetical improvement for rail lines. The allowance per mile of track in the second method ranged from $731 to $3,279.

G.5 Farm Storage Costs

The cost of farm storage is based on the method used by Friesen (Grains Group, Feb., 1971). The costs obtained by him are updated to 1974 conditions and cost levels (Appendix "E"). Storage on farms is required for the volume of grain in excess of commercial elevator capacity. This portion is costed at a constant 9.2¢ per bushel. Any decrease in commercial capacity requires new farm storage to replace lost elevator capacity. This portion is costed at 9.9¢ per bushel[10/].
The cost of loading a grain truck from a farm bin is not incorporated in storage but is included in the trucking cost estimate.

[9/] A carlot is equal to 2,000 bushel of grain.

[10/] The estimate for new storage is similar to the present because it was assumed that steel bins would be used which are depreciated at four percent per year rather than the five percent for present storage.